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ABSTRACT

These instructional materials were developed and designed for secondary and adult limited English proficient students enrolled in machine tool technology courses. Part 1 includes 24 lessons covering introduction, safety and shop rules, basic machine tools, basic machine operations, measurement, basic blueprint reading, layout, and bench tools. Each lesson contains student performance objectives, procedures for the students to follow in progressing through the lesson, information sheets illustrated with line drawings, and references and lesson summaries as needed. These competency-based lessons may be used as a main text, as supplements to other textbooks, or as the basis for a prevocational course in manufacturing trades. (A corresponding student workbook and instructor's manuals are available.) (KC)

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ED220638

Machine Shop Fundamentals: Part I

Illinois State Board of Education

Department of Adult, Vocational and Technical Education

Waubonsee Community College

Edward Copeland
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Donald G. Gill
State Superintendent of Education

Research and Development Section

February, 1982

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FOREWORD

Machine Shop Fundamentals: Part I was developed and designed for secondary and adult limited English proficiency students enrolled in Machine Tool Technology courses. Part I includes an Introduction, Safety and Shop Rules, Basic Machine Tools, Basic Machine Operations, Measurement, Basic Blueprint Reading, Layout, and Bench Tools. These twenty-four competency based lessons may be used as a main text, as supplements to other textbooks, or as the basis for a pre-vocational course in manufacturing trades.

The Illinois State Board of Education is committed to assisting local educational agencies in the development of high quality instructional programs for limited English proficiency and handicapped/disadvantaged students.

The project developed Machine Shop Fundamentals: Part I during two semesters of field-testing with limited English proficiency adults enrolled in Machine Tool Laboratory I. Sincere appreciation is extended to the students, instructors, and consultants who assisted in the development of these instructional materials.

Donald G. Gill

Donald G. Gill
State Superintendent of Education

Illinois State Board of Education

Department of Adult, Vocational and Technical Education
Research and Development Section

Product Abstract

1. Title of material: Machine Shop Fundamentals: Part I

2. Date material was completed: February, 1982

3. Please check one: New material __X__ Revised material ____

4. Originating agency: Waubonsee Community College
   Address: Route 47 at Harter Road, Sugar Grove, IL Zip Code: 60554

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   - ____ 01 Agricultural Education
   - ____ 03 Business and Office Education
   - ____ 04 Distributive Education
   - ____ 07 Health Occupations Education
   - ____ 09 Home Economics Education
   - ____ 10 Industrial Art Education
   - ____ 16 Technical Education
   - __X__ 17 Trade and Industrial Education
   - ____ 22 Cooperative Education
   - ____ Career Education
   - ____ Other (Specify) ____

8. Education Level:

   - ____ Pre-K Thru 6
   - __X__ 7-8
   - __X__ 9-10
   - __X__ 11-12
   - ____ Post-Secondary
   - __X__ Adult
   - ____ Teacher (Pre-service)
   - ____ Administrator (Pre-Service)
   - ____ Other (Specify) ____

9. Intended for Use By:

   - __X__ Student
   - __X__ Classroom Teacher
   - ____ Local Administrator
   - ____ Teacher Educator
   - ____ Guidance Staff
   - ____ State Personnel
   - ____ Other (Specify) ____

10. Student Type:

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    - __X__ Disadvantaged
    - __X__ Handicapped
    - __X__ Limited English Proficiency
    - ____ Other (Specify) ____

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16. General Description (State the general objective and suggested method of use. Summarize the content and tell how it is organized. Continue on back of this sheet or on another sheet, if necessary.):

(See attached General Description on the next page.)

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III/5.2

Machine Shop Fundamentals: Part I was designed for limited English proficiency students who are enrolled in Machine Tool Technologies courses or who are preparing to enroll in Manufacturing Trades courses. The organization, format, and simplified language level of Machine Shop Fundamentals make it suitable not only for LEP students but also for other special needs students who have difficulty reading traditional textbooks. The twenty-four competency based lessons may be used as a main textbook, as a supplementary textbook, or as the basis for a pre-vocational training course.

The lessons include:

Lesson 1 Machine Tool Technology
Lesson 2 Safety Rules
Lesson 3A Basic Machine Tools
Lesson 3B Basic Machine Operations
Lesson 3C Revolutions per Minute, Depth of Cut, and Feed
Lesson 4A Introduction to Measurement
Lesson 4B Semiprecision Measurement
Lesson 4C Precision Measurement with Micrometers
Lesson 4D Precision Measurement with Vernier Calipers and Vernier Height Gages
Lesson 4E Precision Measurement with Dial Indicators
Lesson 5A Introduction to Blueprint Reading
Lesson 5B Basic Views
Lesson 5C Basic Lines
Lesson 5D Tolerances
Lesson 5E Title Blocks
Lesson 6A Introduction to Layout
Lesson 6B Semiprecision Layout
Lesson 6C Precision Layout
Lesson 7A Wrenches, Pliers, and Screwdrivers
Lesson 7B Vises, Clamps, and V-Blocks
Lesson 7C Hacksaws
Lesson 7D Hammers, Chisels, and Punches
Lesson 7E Files
Lesson 7F Taps and Dies

The corresponding Machine Shop Fundamentals: Part I STUDENT WORKBOOK has for each lesson a Technical Vocabulary, Study Questions, Review Questions, and Worksheets.

The VOCATIONAL INSTRUCTOR'S MANUAL has specific teaching strategies and notes, Self-Tests, and student native language supplements in Spanish, Lao, and Vietnamese for each lesson.

The TECHNICAL ENGLISH INSTRUCTOR'S MANUAL has specific vocational English as a second language (VESL) teaching strategies, VESL activities closely coordinated with the Machine Shop Fundamentals lessons, and visuals.

Machine Shop Fundamentals

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Part I

Orientation

Unit 1 Introduction

Lesson 1 Machine Tool Technology

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Lesson 2 Safety Rules

Unit 3 Introduction to Machine Tools and Machine Operations

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Lesson 3C Revolutions Per Minute, Depth of Cut, and Feed

Unit 4 Measurement

Lesson 4A Introduction to Measurement
Lesson 4B Semiprecision Measurement
Lesson 4C Precision Measurement with Micrometers
Lesson 4D Precision Measurement with Vernier Calipers and Vernier Height Gages
Lesson 4E Precision Measurement with Dial Indicators

Unit 5 Blueprint Reading

Lesson 5A Introduction to Blueprint Reading
Lesson 5B Basic Views
Lesson 5C Basic Lines
Lesson 5D Tolerances
Lesson 5E Title Blocks

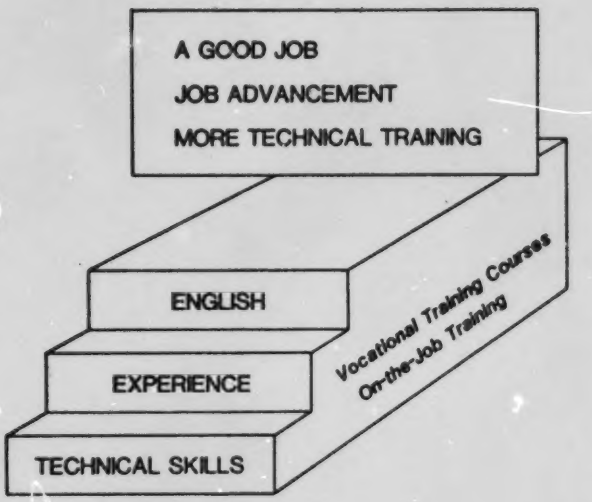
Unit 6 Layout

Lesson 6A Introduction to Layout
Lesson 6B Semiprecision Layout
Lesson 6C Precision Layout

Unit 7 Bench Tools

Lesson 7A Wrenches, Pliers, and Screwdrivers
Lesson 7B Vises, Clamps, and V-Blocks
Lesson 7C Hacksaws
Lesson 7D Hammers, Chisels, and Punches
Lesson 7E Files
Lesson 7F Taps and Dies

INTRODUCTION



To get a good job, people need technical skills, experience and English skills.
Workers need to understand directions, ask questions, and talk with their supervisors and other workers.
This is often a problem for people whose native language is not English.

MACHINE TOOL LABORATORY I	TECHNICAL ENGLISH
- Theory	- Technical Vocabulary
- Practice	- Machine Shop Math
	- "Shop Talk"

This machine tool training program has two classes.
In the Machine Tool Laboratory I classes, students learn the theory and practice of industrial machines in the machine shop.
In the Technical English classes, students learn technical vocabulary, "shop talk," machine shop math, and English skills necessary for Machine Tool Laboratory I and for jobs.
The machine shop teacher and the technical English teacher work together to teach technical machine tool skills and technical English.
Both classes are important for the students.

MACHINE SHOP FUNDAMENTALS: PART I

The student will use the Machine Shop Fundamentals: Part I textbook and student workbook.
The textbook puts the technical information into units and lessons.
The student workbook helps the student study each lesson.
Each lesson has:

Textbook	Student Workbook	Other Materials
Objectives	Technical Vocabulary	Slide Show
Procedures	Study Questions	Native Language Supplements
Technical Information	Review Questions	Self-Test

The student must pass the Self-Test with 80% or more correct answers before he/she studies the next lesson.
The lesson is the theory part of the class.
In the machine shop, the student must understand the theory before he/she sets up and runs a machine tool.

For the course, the student will need:

1. Safety glasses
2. A 6" machinist's rule
3. A thick 3-ring notebook
4. A vise (DVP #54)

SCHEDULE

MACHINE TOOL LABORATORY I	6 hours per week
TECHNICAL ENGLISH	10 hours per week
STUDY TIME AT HOME	6 hours per week
TOTAL	22 hours per week

The student must study 6 hours per week at home.

GRADES

Each student will receive a grade for the Machine Tool Laboratory I course.

Average Grade Points:

90 - 100	A (Superior)
80 - 89	B (Good)
70 - 79	C (Average)
60 - 69	D (Poor)
59 or below	F (Failure)

60% of the grade points are from the student's work in the Machine Shop.
40% of the grade points are from the student's examinations and tests.

The student will aso receive a grade for the Technical English course.

ATTENDANCE

On the job, attendance is very important.
Workers must be at their jobs everyday and must be on time.
In school, attendance is also very important.
If a worker does not go to his/her job everyday, he/she gets fired.
If a student does not go to school everyday, he/she will not learn and will fail the course.
Attendance in school is like attendance on the job.

Sometimes a worker cannot go to his/her job because of sickness or family problems.
Then he/she must call the company.
If a student cannot go to school, he/she must call the teacher.

If you cannot go to school, call _____.

MACHINE TOOL COURSES AT WAUBONSEE COMMUNITY COLLEGE

Waubonsee Community College has nine courses in Machine Tool Technology:

Machine Tool Laboratory I	Metallurgy and Heat Treatment
Machine Tool Laboratory II	Strengths of Materials
Machine Tool Laboratory III	Metrology
Manufacturing Processes	Introduction to Numerical Control
Die Design and Construction	

All students begin with Machine Tool Laboratory I (one).
In Machine Tool Laboratory I, students learn to use basic measuring tools in the machine shop and to do basic machine tool operations with these machine tools:

The horizontal bandsaw
The vertical bandsaw
The engine lathe
The horizontal mill
The vertical mill
The drill press
The radial drill
The surface grinder

Students study the theory and practice of machine tools in the machine shop.

When a student finishes Machine Tool Laboratory I (one) he/she has basic technical skills and experience to begin work as a machine operator, to take a better job in the company where he/she works, or to take more advanced classes.

After Machine Tool Laboratory I (one), many students take Machine Tool Laboratory II (two).
Please ask the teacher if you want more information about the program and classes.

Machine Shop Fundamentals

1

UNIT 1: Introduction

LESSON 1: Machine Tool Technology

OBJECTIVES:

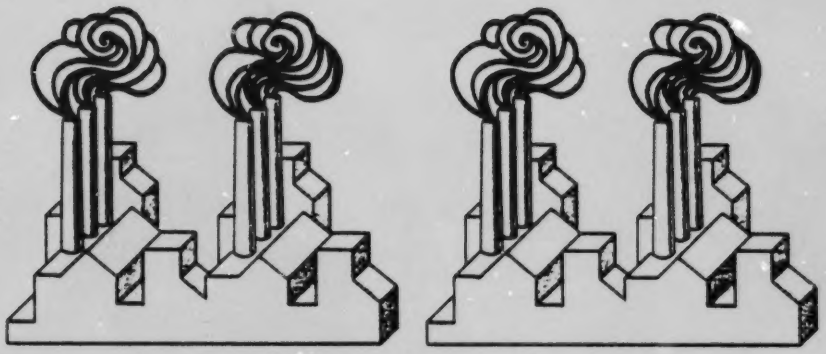
1. The student will write what machine tools make.
2. The student will write the reason why accurate sizes of parts are important.
3. The student will choose the correct order of steps that a machinist follows for a machine operation.
4. The student will choose the reasons why a machinist must know good math.

PROCEDURES:

1. Read the Objectives.
2. Read the Lesson.
3. Watch the Slide Show.
4. Do the Study Questions.
5. Do the Review Questions.
6. Do the Self-Test.

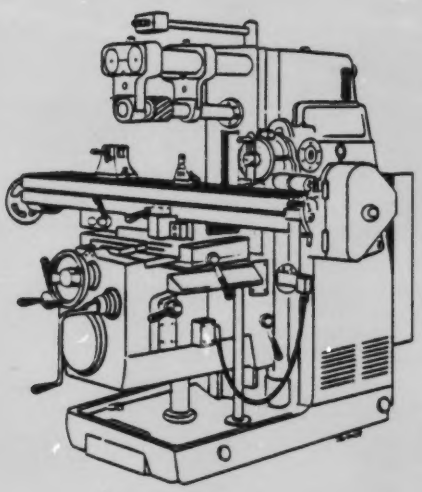
REFERENCES:

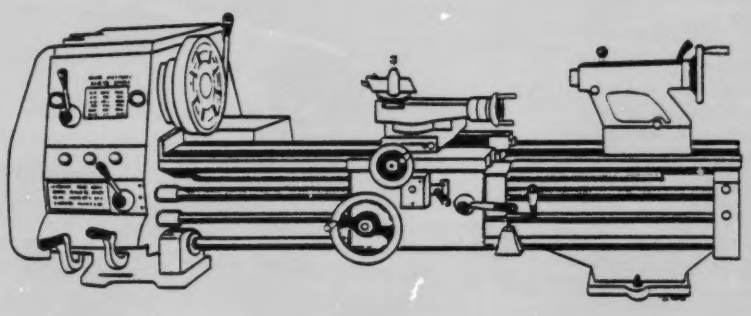
INTRODUCTION



Everyone wants a good job.
The United States has many factories.
Many people work in factories.
People need technical skills and experience to get good jobs in factories.
A person can get technical skills and experience in vocational training courses and on the job.

Everyone depends on machines for transportation, food, homes, employment, and much more.
Factories build machines.
Machinists are an important group of workers in factories.
A machinist uses industrial machines to make the metal parts for many other machines.



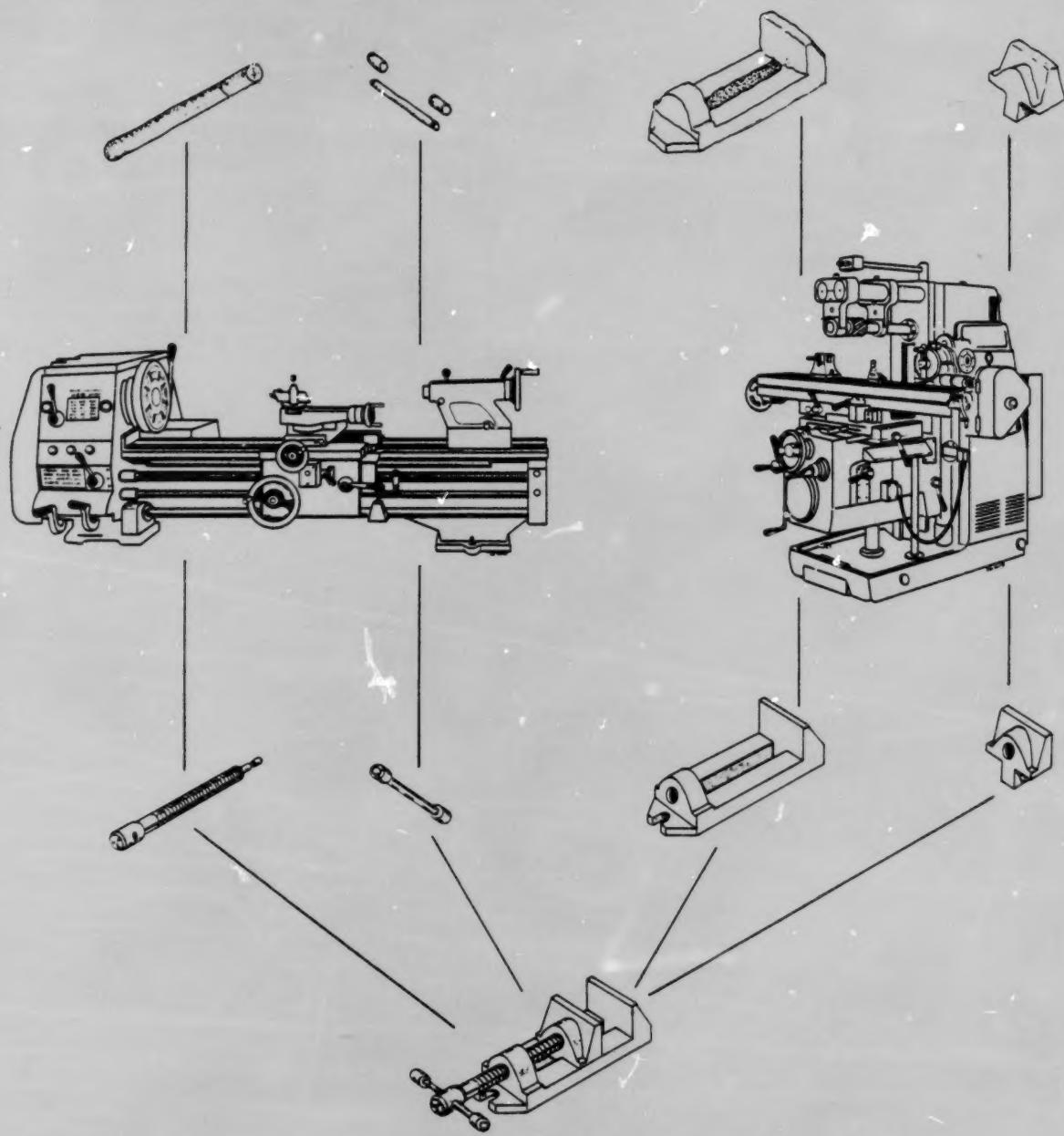


These industrial machines are called machine tools.
Machine tools make metal parts for new machines and other products.

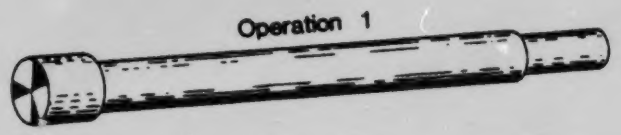
With machine tools, a machinist makes parts to very accurate sizes.

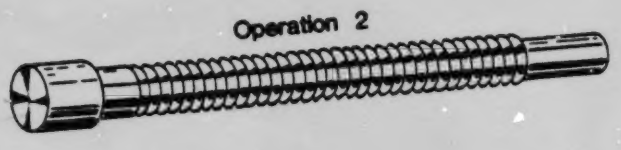
Why?

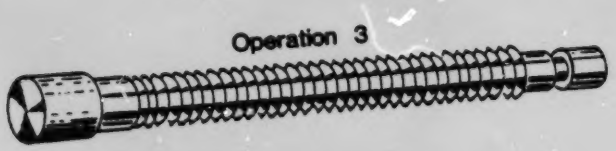
Accurate sizes of parts are important because many different parts must fit together to make a new machine.

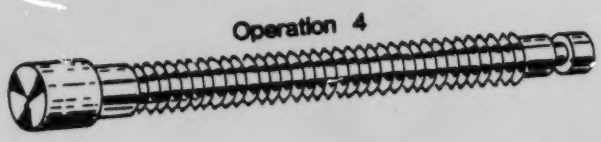


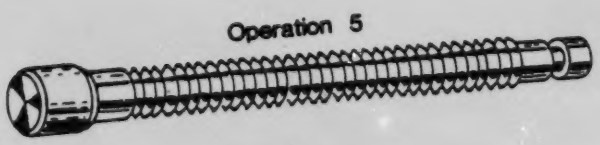
Each part must have accurate sizes.
If the sizes of one part are not accurate, the part will not fit with the other parts.

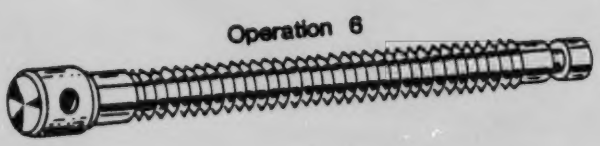












Most parts need several machine operations.
To make a finished part, usually several machinists must do different operations, and they must use different machine tools.

Factories want to make accurate parts in the cheapest way possible.
The cheapest way is mass production.
In mass production, one machinist does the same operation or operations on many of the same parts.
Then, another machinist does a different operation on the same parts.

When these parts are finished, assembly line workers put them together with other finished parts.

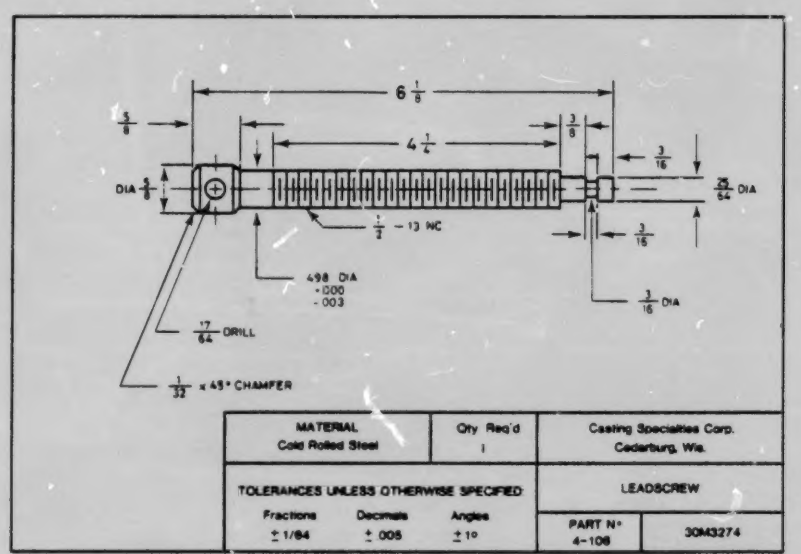
WHAT IS A MACHINIST?

A machinist works in the machine shop of a factory.
He/she uses machine tools to make metal parts for other machines.
There are many different kinds of machine tools and machine operations.
Most machine tools are complicated.
A machinist must have a lot of technical skills and shop experience.
A person must study machine tool theory and math, and must work for several years to be a skilled machinist.

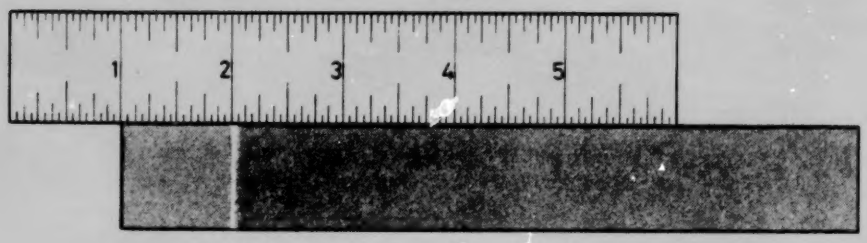
A skilled machinist makes good money.
In the future, employment for skilled machinists will be very good.
Factories will have more machine tools and the machine tools will be more complicated than now.
Factories will need many skilled machinists to use the machine tools.

WHAT DOES A SKILLED MACHINIST DO?

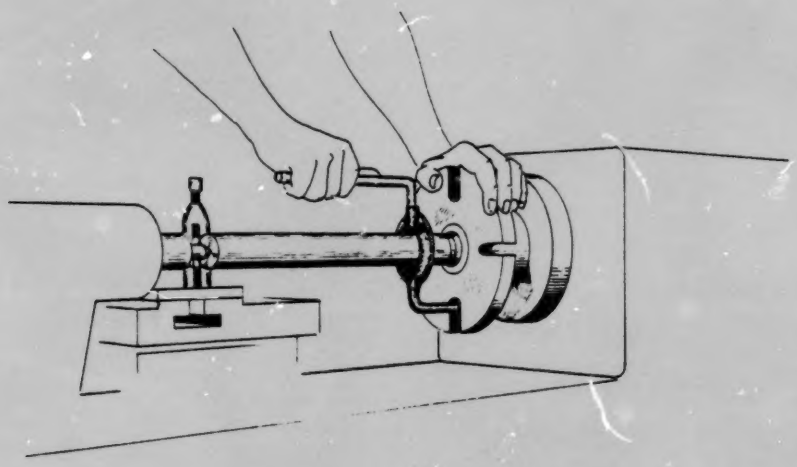
A skilled machinist uses machine tools to make metal parts for new machines and other products.
How does a skilled machinist make metal parts for other machines?
For a machine operation, a skilled machinist usually follows these steps:



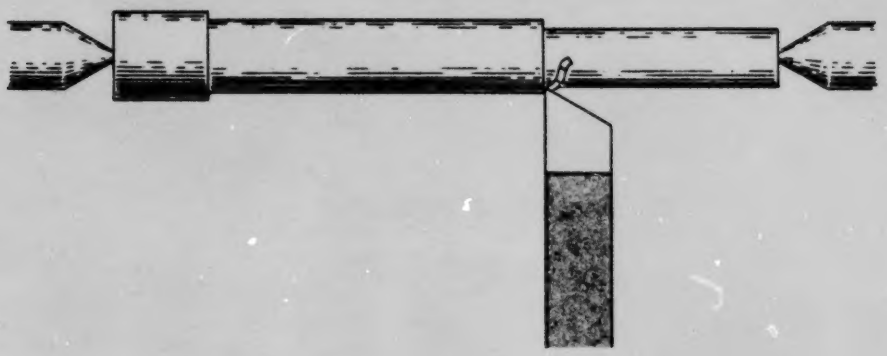
STEP 1. The machinist reads the blueprint of the finished part.
The blueprint shows the shape and exact sizes of the finished part.
The blueprint also gives technical information about the finished part and the operations.



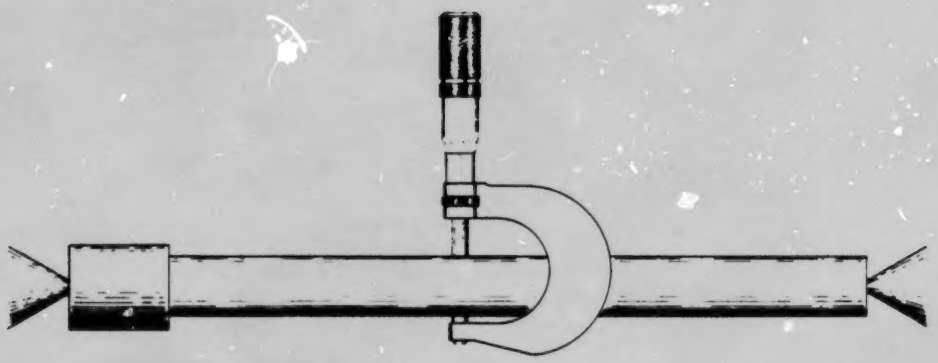
STEP 2. The machinist lays out the part.
To lay out a part, the machinist marks the correct sizes on the part.



STEP 3. The machinist sets up the machine tool.
To set up the machine tool, the machinist gets the machine tool ready for the operation.



STEP 4. The machinist runs the machine tool to do the different operations. To run a machine tool means to operate it.



STEP 5. The machinist measures the part to check the sizes of the part. He/she compares the sizes of the part to the exact sizes on the blueprint.
The machinist measures the part often to check it.

MACHINE SHOP MATH

Math is very important for machinists.

Why?

1. To read the blueprints.
2. To lay out parts.
3. To measure parts and check sizes.

Machinists must know and understand fractions and decimal numbers.

MACHINE SHOP THEORY

Machine shop theory is very important for machinists.

Why?

1. To make correct set-ups.
2. To understand the machine tools, the cutters of the machine tools, and the metals of the parts.
3. To run the machine tools.

UNIT 2: Safety in the Machine Shop

LESSON 2: Safety Rules

OBJECTIVES:

1. The student will choose the correct Safety Rules about clothing in the machine shop.
2. The student will choose the correct Safety Rules about clean-up in the machine shop.
3. The student will choose the correct Safety Rules about accidents in the machine shop.
4. The student will choose the correct Safety Rules about fires in the machine shop.
5. The student will choose the correct Safety Rules about safe things that the machinist must do in the machine shop.
6. The student will choose the correct Safety Rules about unsafe things that the machinist must not do in the machine shop.

PROCEDURES:

1. Read the Objectives.
2. Read the Lesson.
3. Watch the Slide Show.
4. Do the Study Questions.
5. Do the Review Questions.
6. Do the Self-Test.

REFERENCES:

INTRODUCTION

Safety means to be careful.
Safety means not to have accidents.

Companies design machine tools to be safe.
Factories try to protect the machinist from accidents.
Machine shops have safety rules and signs to protect the machinist from accidents.
Machine shops have shop rules to protect the machinist from accidents.

Safety is very important in schools and in factories.
Machine tools are very powerful, and they can be dangerous.
Accidents hurt people, break machine tools and parts, and cost money.
People cause most accidents.
A machinist must always follow safety rules, just like a driver must follow traffic laws and safety rules on the road.

Machine tools and machines do not cause many accidents.
But machine tools and machines are not perfect.
Machine tools and machines can break and not work correctly.
Machine tools and machines cause some accidents.

Sometimes a new machinist causes an accident because he/she does not know how to use a machine tool or other tools.
Knowledge of the safety rules and the correct ways to use the machine tools and other tools is very important.
Lack of knowledge can cause an accident.
The machinist must know the safety rules and must follow the safety rules.
The machinist must know how to use machine tools and other tools.

Sometimes, a skilled machinist causes an accident because he/she is in a hurry.
The machinist in a hurry does not follow safety rules.
The machinist in a hurry thinks that he/she can cheat on safety rules and still be safe.
He/she is very wrong.
When a machinist is in too much of a hurry to be careful, he/she can cause a bad accident.

Machines can't think, but people can think.
Students and machinists must think to use their knowledge and to follow safety rules.

An accident can hurt the machinist.
An accident can hurt other people.
An accident can break machine tools and parts.
An accident can waste time and money.

Always be careful.
Learn the safety rules.
Follow the safety rules.
Ask questions if you are not sure of something.
Do not be in a hurry.
Think.

MACHINE SHOP SAFETY RULES

CLOTHING IN THE MACHINE SHOP

1. Always wear your safety glasses.
2. Roll up the sleeves on your shirt above your elbows.
3. Take off your jewelry before you run a machine tool.
   (Jewelry means: rings, watches, bracelets, necklaces, medals.)
4. Keep long hair away from moving machine parts.
   (Tie long hair back or wear a hair net.)

CLEAN-UP IN THE MACHINE SHOP

1. Clean up oil on the floor.
2. Clean up your machine tools and work area before you leave the shop.
3. Put all tools in the correct place.
4. Keep the aisles clear between the machine tools.
5. Put oily shop towels in the correct container.
   (This container is a special metal can.)

ACCIDENTS

1. Tell your teacher or foreman about all injuries from accidents.
2. Tell your teacher or foreman about all damage from accidents.

FIRES

1. Know where the fire alarms are in the shop.
2. Learn when and how to use the fire alarms.
3. Know where the fire extinguishers are in the shop.
4. Learn when and how to use the fire extinguishers.
5. Know where the fire exits are in the shop.

SAFE THINGS: THINGS YOU MUST DO

1. Learn how to operate a machine tool before you start.
2. Always follow the instructions of your teacher or foreman.
3. Tighten all machine parts and cutters before you start a machine tool.
4. Keep your fingers away from moving parts of a machine tool.
5. Shut off your machine tool before you walk away to work in a different place.
6. Shut off your machine tool before you adjust or measure anything.
7. Shut off your machine tool before you clean it.
8. Tell your teacher or foreman about broken machine tools, measurement tools, or parts.
9. Ask for help to carry heavy things.

UNSAFE THINGS: THINGS YOU MUST NOT DO

1. Do not operate a machine tool before your teacher comes.
2. Do not operate a machine tool after you drink alcoholic beverages.
3. Do not operate a machine tool after you take strong medicine or drugs.
4. Do not bother other students or workers.
5. Do not fool around near the machine tools.
6. Do not waste time in the shop or on the job.
7. Do not touch another machinist's machine tool. (Only one machinist operates one machine tool.)
8. Do not touch moving parts of a machine tool.
9. Do not use your hands to stop moving parts of a machine tool.
10. Do not use your hands to brush metal chips off a machine tool.

Machine Shop Fundamentals

3A

UNIT 3: Introduction to Machine Tools and Machine Operations

LESSON 3A: Basic Machine Tools

OBJECTIVES:

1. The student will choose what the cutters of all machine tools do.
2. The student will match the name of a machine tool to the use of that machine tool.
3. The student will choose the correct name of the cutter of each machine tool.

PROCEDURES:

1. Read the Objectives.
2. Read the Lesson.
3. Watch the Slide Show.
4. Watch the teacher's Demonstration.
5. Do the Study Questions.
6. Do the Review Questions.
7. Do the Self-Test.

REFERENCES:

INTRODUCTION

A machinist uses industrial machines to make parts for many new machines and products.
These industrial machines are called machine tools.
There are many different kinds of machine tools.
There are machine tools for metal parts, for plastic parts, and for woodworking.
Machine Shop Fundamentals is about machine tools for metal parts.

With machine tools, a machinist makes parts to very accurate sizes.
Accurate sizes of parts are important because many different parts must fit together to make a new machine or product.
Each part must have accurate sizes.

Each machine tool has a cutter.
There are many different kinds of cutters.
Machinists use different kinds of cutters for different machine tools and machine operations.
But all cutters cut metal chips from the part.

In this lesson, you will learn about these machine tools:

THE HORIZONTAL BANDSAW

THE VERTICAL BANDSAW

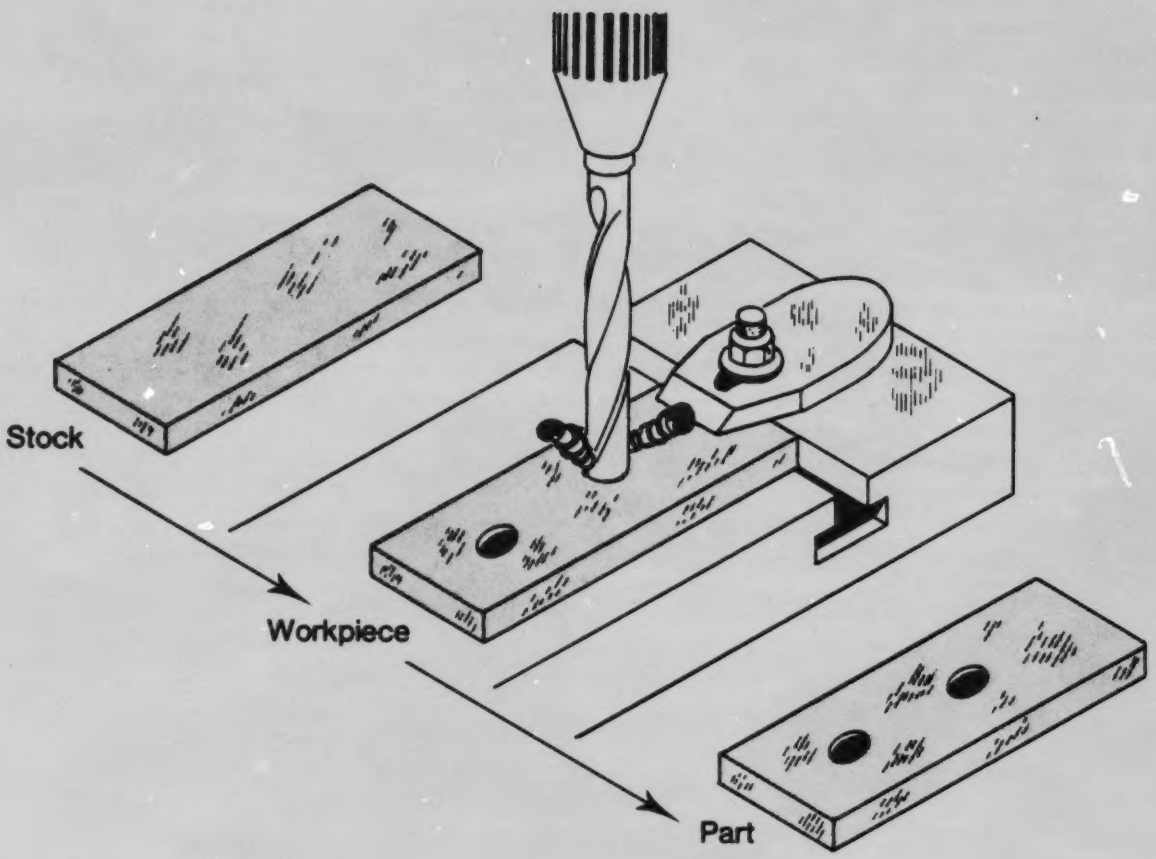
THE ENGINE LATHE

THE HORIZONTAL MILL

THE VERTICAL MILL

THE DRILL PRESS

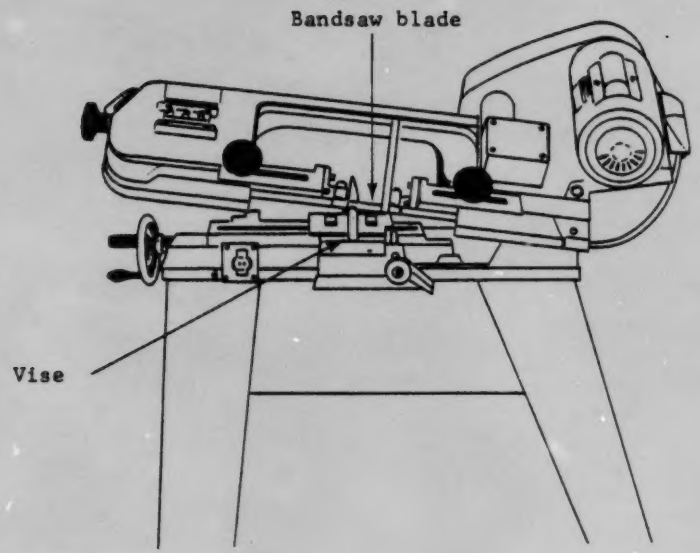
THE SURFACE GRINDER



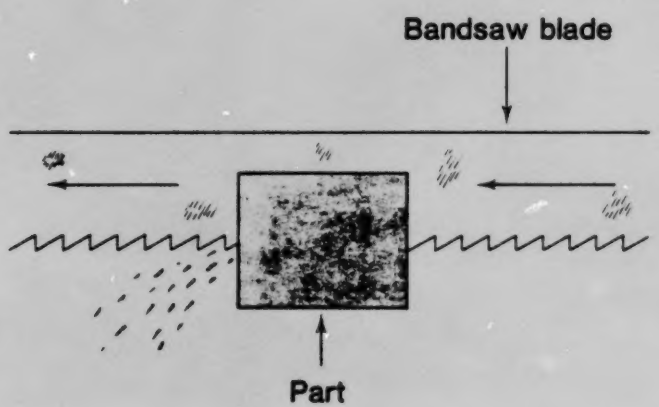
Sometimes, a machinist does not make parts in mass production.
Sometimes, he/she must make a special part.
He/she does all the machine operations on this part.
The machinist starts with stock.
Stock is large pieces of metal.
The machinist cuts off a piece of stock.
The piece of stock is a little bigger than the finished part.
Remember, the blueprint shows the shape and the exact sizes of the finished part.

Now the piece of metal is sometimes called a workpiece.
Most textbooks and charts call it a workpiece.
In the shop and in Machine Shop Fundamentals, we call it a part.
The machinist does machine operations on the part (workpiece) to make the finished part.

HORIZONTAL BANDSAW



This is a HORIZONTAL BANDSAW.
The machinist uses a horizontal bandsaw to cut parts to size.
The machinist saws parts to size on a horizontal bandsaw.

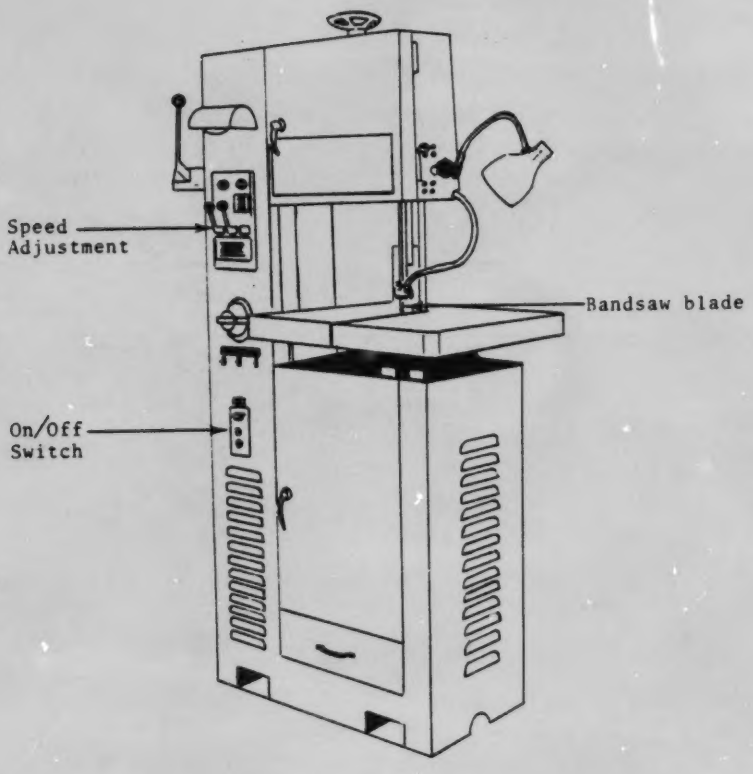


The cutter of a horizontal bandsaw cuts metal chips to cut a part to size.

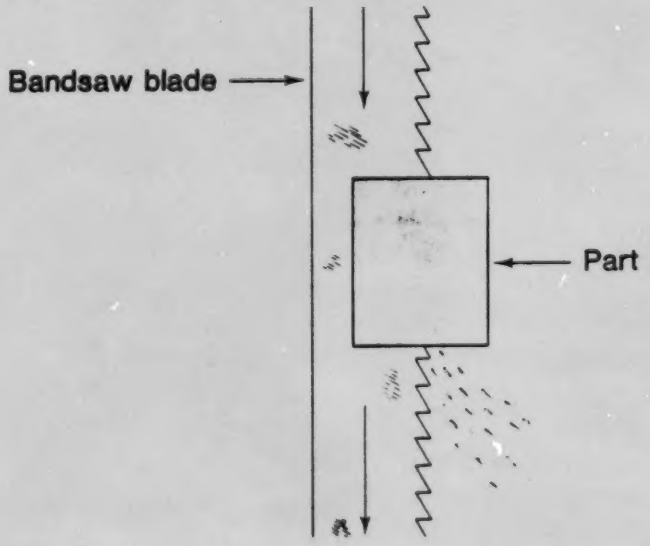
The cutter of a horizontal bandsaw is called a BANDSAW BLADE.

The horizontal bandsaw revolves the bandsaw blade.

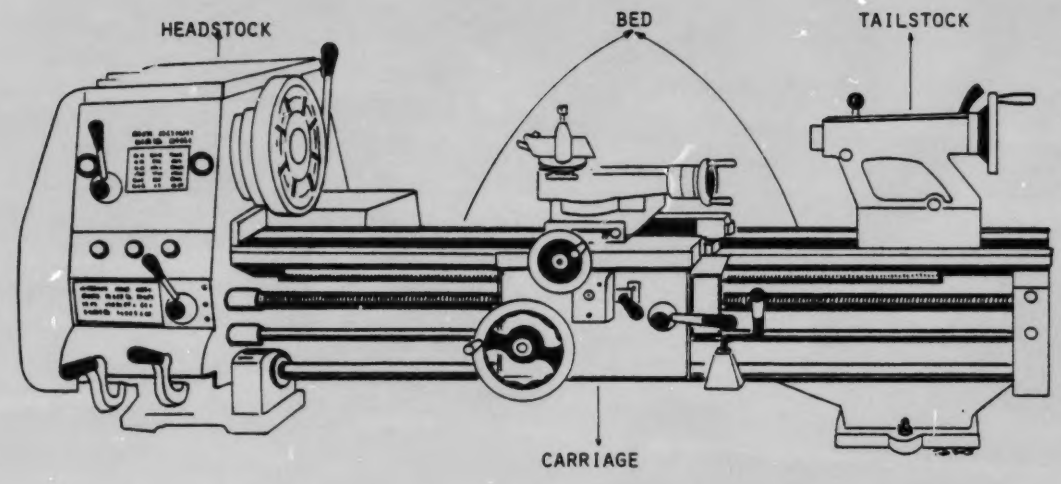
VERTICAL BANDSAW



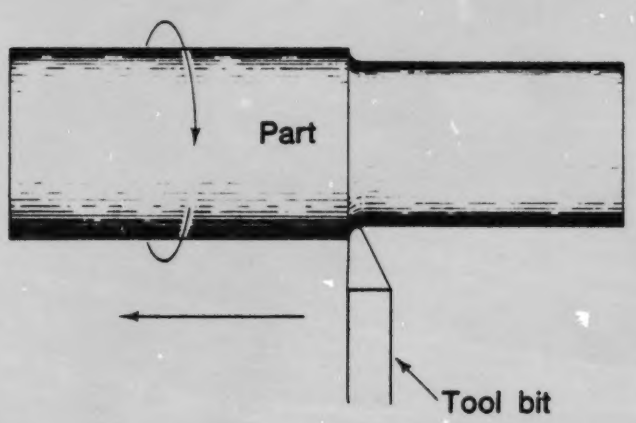
This is a VERTICAL BANDSAW.
The bandsaw blade of the vertical bandsaw is vertical.
The bandsaw blade of the horizontal bandsaw is horizontal.
The machinist uses the vertical bandsaw like the horizontal bandsaw.
The vertical bandsaw revolves the bandsaw blade.
The machinist saws parts on the vertical bandsaw.



LATHE



This is a LATHE.
The machinist uses a lathe to make round parts.
The machinist turns round parts on a lathe.
Many times in the machine shop, a round part means a cylindrical part.



The cutter of a lathe cuts metal chips to make round parts.

The cutter of a lathe is called a TOOL BIT.

The lathe revolves the part.

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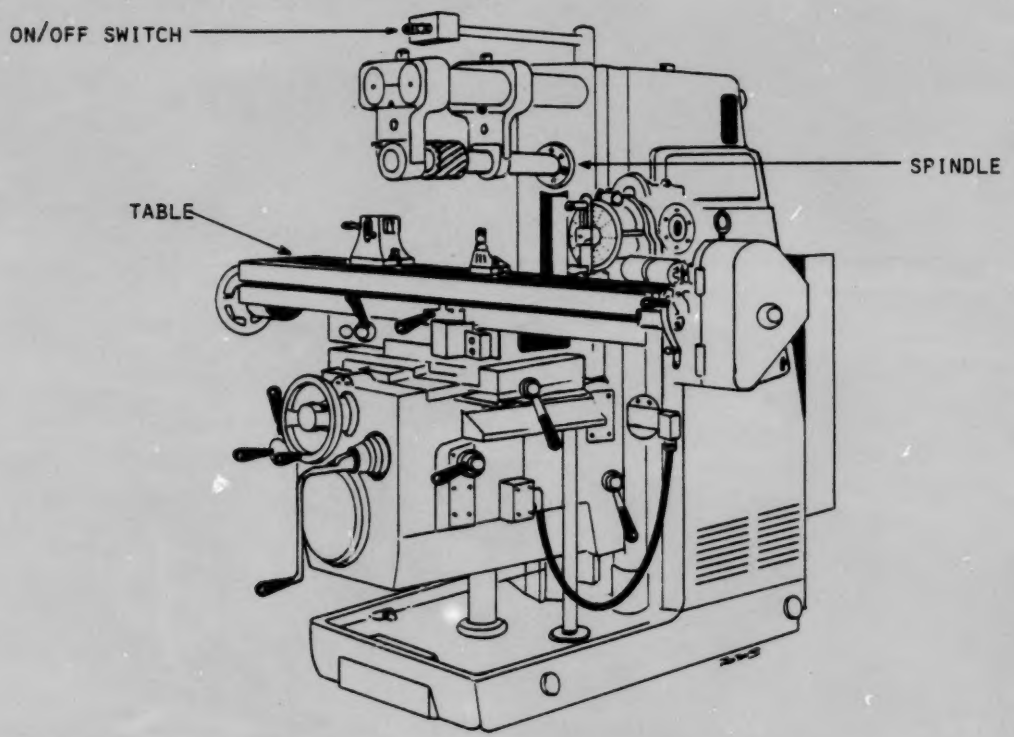
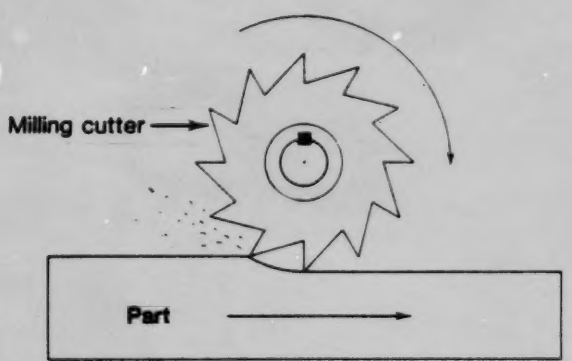
HORIZONTAL MILL



This is a HORIZONTAL MILL.
The machinist uses a horizontal mill to make flat, smooth surfaces on parts.
The machinist also uses a horizontal mill to make slots in parts.
The machinist mills surfaces and slots in parts on a horizontal mill.

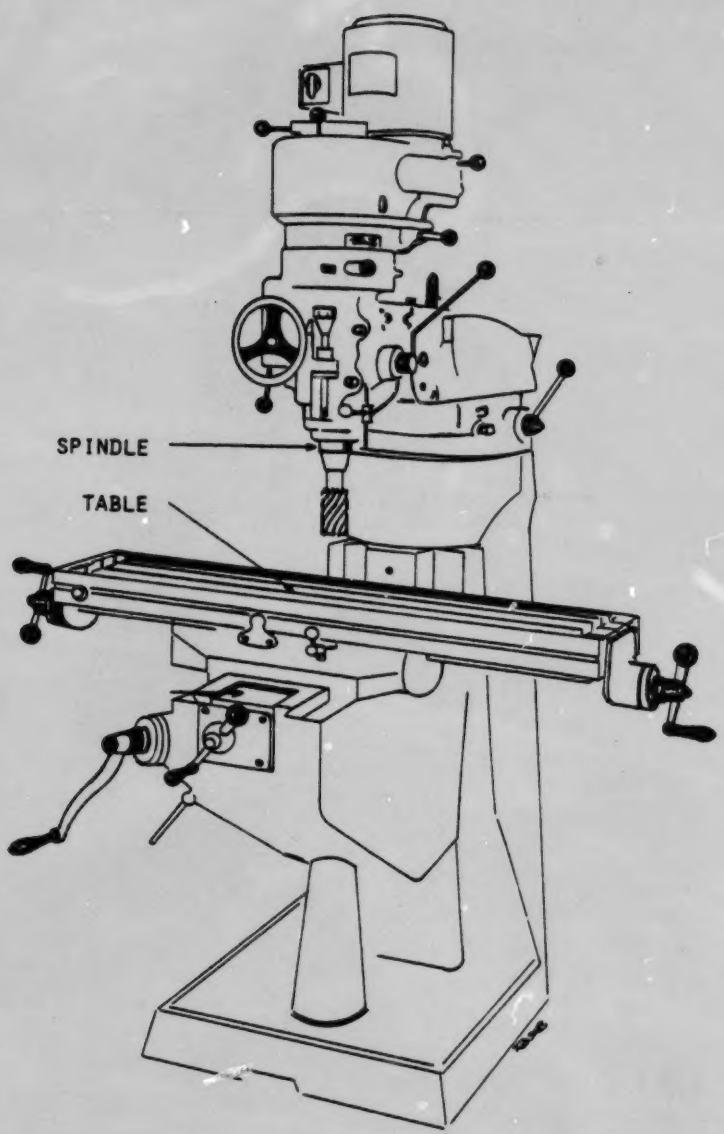


The cutter of a horizontal mill cuts metal chips to make flat, smooth surfaces on parts and to make slots in parts.

The cutter of a horizontal mill is called a MILLING CUTTER.

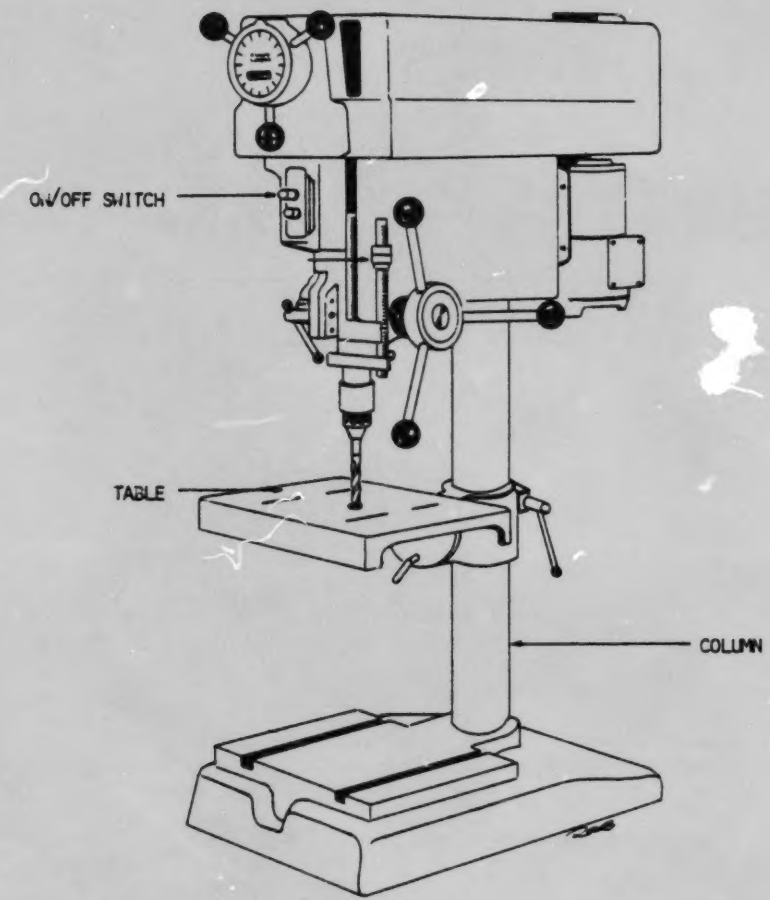
The horizontal mill revolves the milling cutter.

VERTICAL MILL

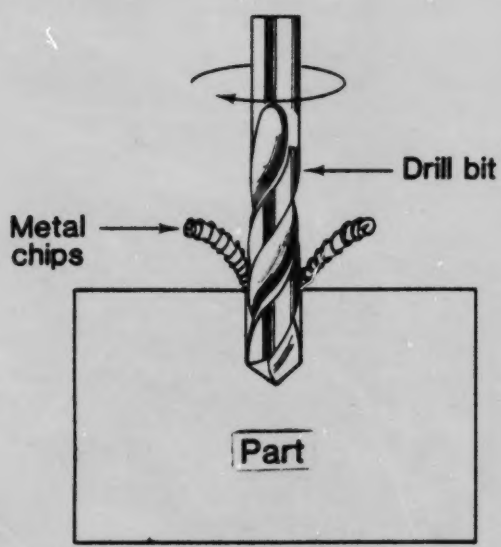


This is a VERTICAL MILL.
The spindle of the vertical mill is vertical.
The spindle of the horizontal mill is horizontal.
The machinist uses the vertical mill like the horizontal mill.
The cutter of a vertical mill is called a MILLING CUTTER.
The machinist mills parts on the vertical mill.

DRILL PRESS



This is a DRILL PRESS.
The machinist uses a drill press to make holes in parts.
The machinist drills holes in parts on a drill press.

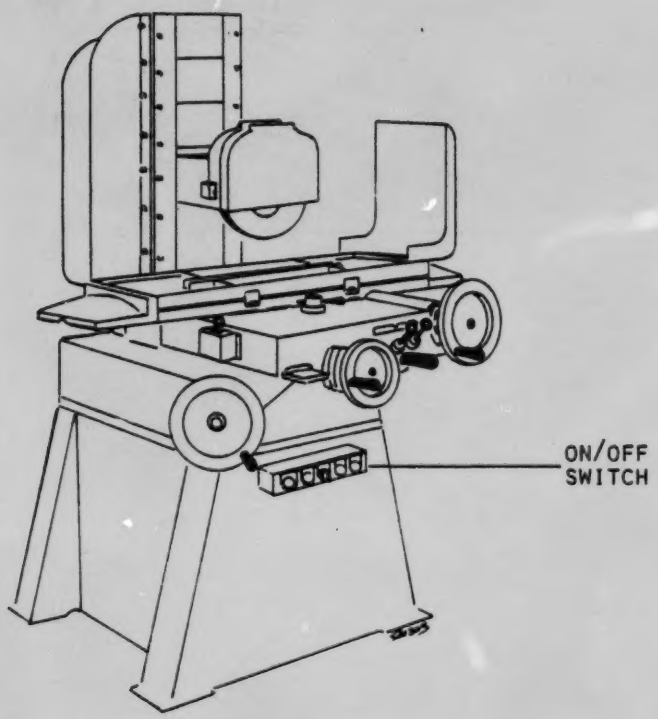


The cutter of a drill press cuts metal chips to make holes in parts.

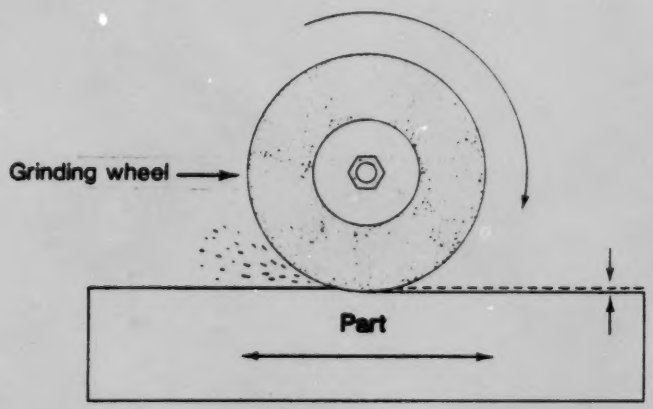
The cutter of a drill press is called a DRILL BIT.

The drill press revolves the drill bit.

SURFACE GRINDER



This is a SURFACE GRINDER.
The machinist uses the surface grinder to make flat and very smooth surfaces on parts.
The machinist grinds flat and very smooth surfaces on parts on a surface grinder.



The cutter of a surface grinder cuts very small metal chips from the part.

The cutter of a surface grinder is called a GRINDING WHEEL.

The surface grinder revolves the grinding wheel.

SUMMARY

Each machine tool has a cutter.

What do the cutters of all machine tools do?

All cutters cut metal chips from parts.

MACHINE TOOL	CUTTER
Horizontal bandsaw	Bandsaw blade
Vertical bandsaw	Bandsaw blade
Engine lathe	Tool bit
Horizontal mill	Milling cutter
Vertical mill	Milling cutter
Drill press	Drill bit
Surface grinder	Grinding wheel

Machine Shop Fundamentals

3B

UNIT 3: Introduction to Machine Tools and Machine Operations

LESSON 3B: Basic Machine Operations

OBJECTIVES:

1. The student will match the name of a machine operation to a picture of that machine operation.
2. The student will match the name of a machine operation to a description of that machine operation.
3. The student will choose the machine tool that the machinist uses to do a machine operation.

PROCEDURES:

1. Read the Objectives.
2. Read the Lesson.
3. Watch the Slide Show.
4. Watch the teacher's Demonstration.
5. Do the Study Questions.
6. Do the Review Questions.
7. Do the Self-Test.

REFERENCES:

INTRODUCTION

A machinist uses machine tools to make parts for many new machines and products.
He/she does machine operations on a part to make the finished part.
A machine operation is the method (the way) to cut off metal chips from a part to change the size and shape of the part.
Remember, the blueprint shows the shape and the exact sizes of the finished part.
The cutter of a machine tool cuts metal chips from a part.
A machinist does machine operations on parts with machine tools.

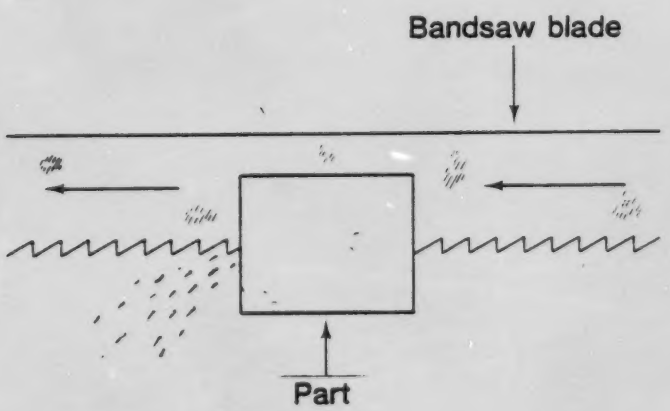
Most parts need several machine operations.
To make finished parts, usually several machinists must do several different machine operations, and they must use different machine tools.
This is mass production.
Machine operations change the size and shape of a part according to blueprint specifications.
Machinists do machine operations on parts with machine tools.

There are many different kinds of machine operations.
In this unit, you will learn about these 5 basic machine operations:

1. SAWING
2. TURNING
3. MILLING
4. DRILLING
5. GRINDING

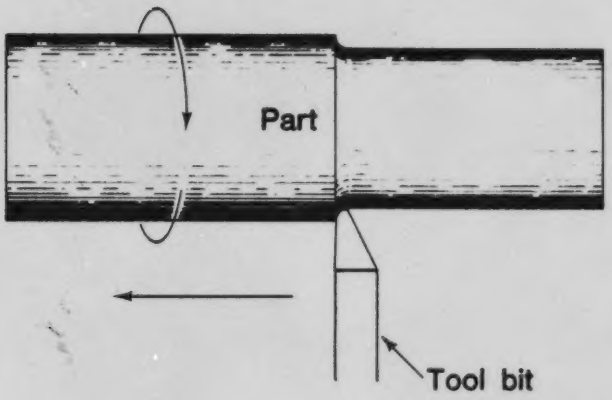
1. SAWING Cutting parts to size is a machine operation.
Cutting parts to size with a bandsaw blade is called SAWING.
SAWING is a machine operation.
The machinist does SAWING operations on the horizontal bandsaw and the vertical bandsaw.

SAWING



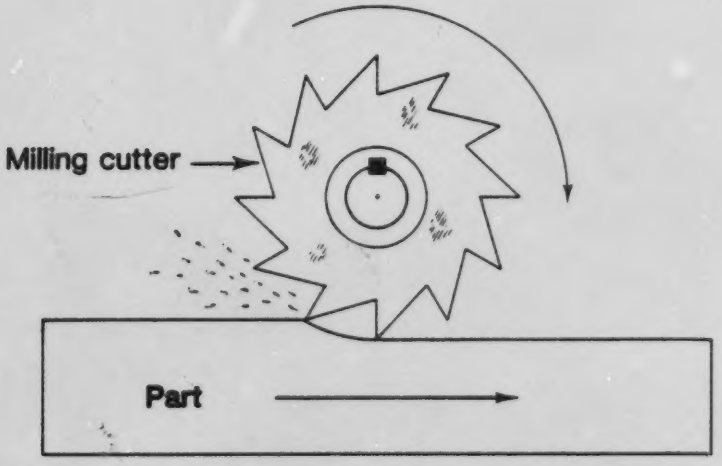
2. TURNING Making round parts is a machine operation.
Making round parts with a tool bit is called TURNING.
TURNING is a machine operation.
The machinist does TURNING operations on the lathe.
Many times in the machine shop, a round part means a cylindrical part.

TURNING



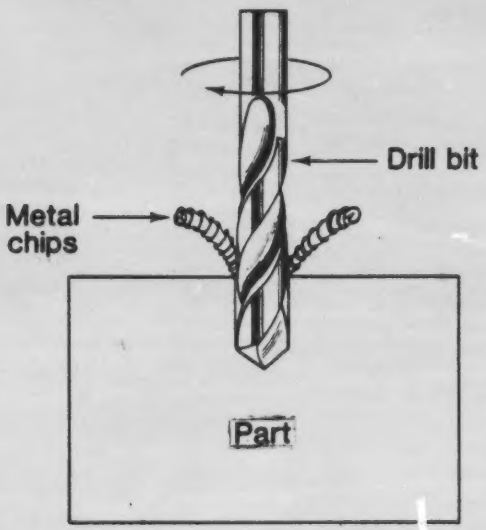
3. MILLING Making flat, smooth surfaces on parts is a machine operation.
Making slots in parts is a machine operation.
Making flat, smooth surfaces and slots with a milling cutter is called MILLING.
MILLING is a machine operation.
The machinist does MILLING operations on the horizontal mill and the vertical mill.

MILLING



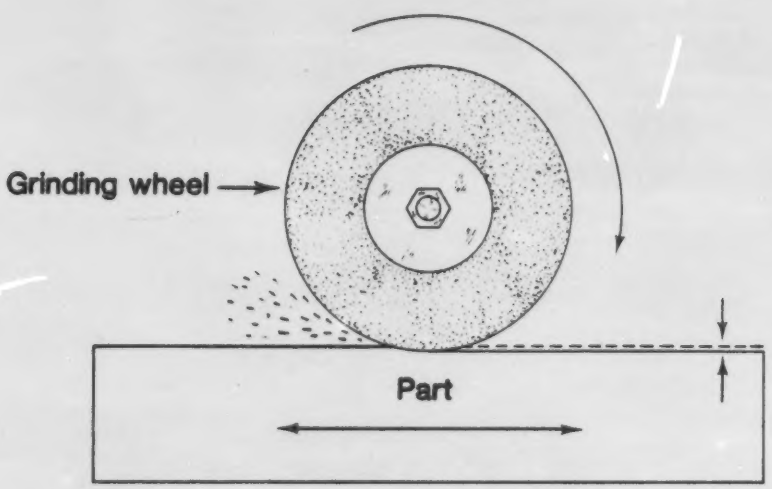
4. DRILLING Making holes is a machine operation.
Making holes in parts with a drill bit is called DRILLING.
DRILLING is a machine operation.
The machinist usually does DRILLING operations on the drill press.
The machinist also can do DRILLING operations on the lathe and the vertical mill.

DRILLING



5. GRINDING Making flat and very smooth surfaces on parts is a machine operation.
Making flat and very smooth surfaces on parts with a grinding wheel is called GRINDING.
GRINDING is a machine operation.
The machinist does GRINDING operations on the surface grinder.

SURFACE GRINDING



SUMMARY

Cutting parts to size with a bandsaw blade is called SAWING.
Making round parts with a tool bit is called TURNING.
Making flat, smooth surfaces on parts or slots in parts with a milling cutter is called MILLING.
Making holes in parts with a drill bit is called DRILLING.
Making flat and very smooth surfaces on parts with a grinding wheel is called GRINDING.

MACHINE OPERATION	MACHINE TOOL
Sawing	Horizontal bandsaw Vertical bandsaw
Turning	Lathe
Milling	Horizontal mill Vertical mill
Drilling	Drill press Lathe Vertical mill
Grinding	Surface grinder

The machinist saws parts to size on a horizontal bandsaw and a vertical bandsaw.
The machinist turns round parts on a lathe.
The machinist mills surfaces and slots in parts on a horizontal mill and a vertical mill.
The machinist drills holes in parts on a drill press, a lathe, and a vertical mill.
The machinist grinds flat and very smooth surfaces on parts on the surface grinder.

These are the 5 basic machine operations.
In later lessons, you will learn more about each basic machine operation.
Also, you will learn how the machinist uses the machine tools to make parts.

Machine Shop Fundamentals

3C

UNIT 3: Introduction to Machine Tools and Machine Operations

LESSON 3C: Revolutions Per Minute, Depth of Cut, and Feed

OBJECTIVES:

1. The student will write the 3 factors a machinist must understand to set up machine tools and to do machine operations.
2. The student will match the steps to do a machine operation on the horizontal mill to the pictures of those steps.
3. The student will match the steps to do a machine operation on the lathe to the pictures of those steps.

PROCEDURES:

1. Read the Objectives.
2. Read the Lesson.
3. Watch the Slide Show.
4. Watch the teacher's Demonstration.
5. Do the Study Questions.
6. Do the Review Questions.
7. Do the Self-Test.

REFERENCES:

INTRODUCTION

A machinist uses machine tools to make parts for many new machines and products.
In Lesson 3A, you learned about these machine tools and their cutters:

MACHINE TOOL	CUTTER
HORIZONTAL BANDSAW	BANDSAW BLADE
VERTICAL BANDSAW	BANDSAW BLADE
ENGINE LATHE	TOOL BIT
HORIZONTAL MILL	MILLING CUTTER
VERTICAL MILL	MILLING CUTTER
DRILL PRESS	DRILL BIT
SURFACE GRINDER	GRINDING WHEEL

With machine tools, a machinist makes parts to very accurate sizes.
Accurate sizes of parts are important because many different parts must fit together to make a new machine or product.
Each part must have accurate sizes.

A machinist does machine operations on a part to make the finished part.
A machine operation is the method (the way) to cut off metal chips from a part to change the size and shape of the part.
The cutter of a machine tool cuts metal chips from a part.

Machine operations change the size and shape of a part according to blueprint specifications.
Machinists do machine operations on parts with machine tools.

In Lesson 3B, you learned about these basic machine operations:

SAWING
TURNING
MILLING
DRILLING
GRINDING

To set up machine tools and to do machine operations on parts, a machinist must understand these factors:

1. REVOLUTIONS PER MINUTE (RPM)
2. DEPTH OF CUT
3. FEED

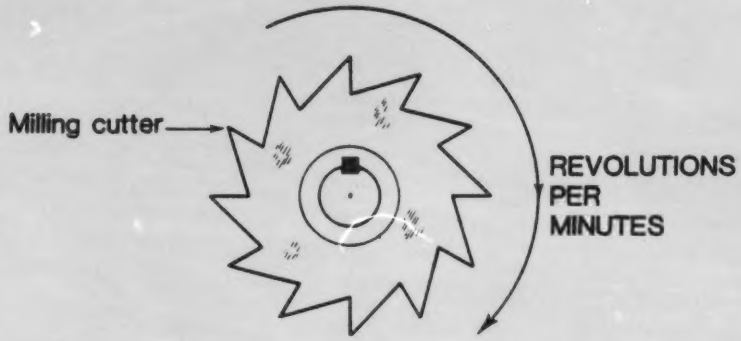
A machinist uses his/her knowledge and experience to set the correct revolutions per minute (RPM), depth of cut, and feed on a machine tool.

REVOLUTIONS PER MINUTE (RPM)

Most machine tools have a SPINDLE.
An electric motor and gears inside the machine tool revolve the spindle.
When the electric motor and gears revolve the spindle one time, this is 1 revolution.
75 revolutions of the spindle in one minute are 75 revolutions per minute (RPM).
The abbreviation for revolutions per minute is RPM.

On some machine tools, like the horizontal mill, the spindle revolves the cutter.
On these machine tools, when the spindle makes 1 revolution, the cutter also makes 1 revolution.

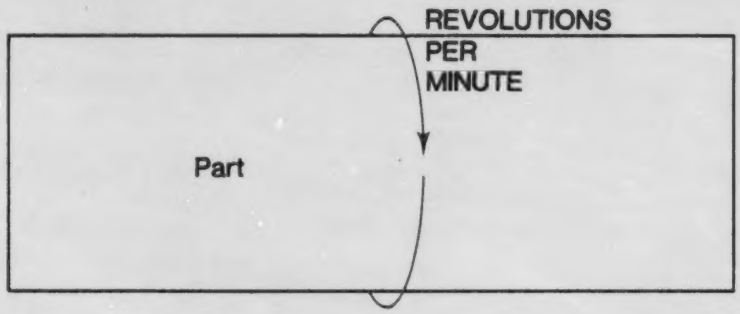
EXAMPLE A



In EXAMPLE A, the spindle of the horizontal mill revolves the milling cutter.
On the horizontal mill, 123 RPM means the milling cutter makes 123 revolutions in one minute.

On some machine tools, like the lathe, the spindle revolves the part.
On these machine tools, when the spindle makes 1 revolution, the part also makes 1 revolution.

EXAMPLE B



In EXAMPLE B, the spindle of the lathe revolves the part.
On the lathe, 300 RPM means the part makes 300 revolutions in one minute.

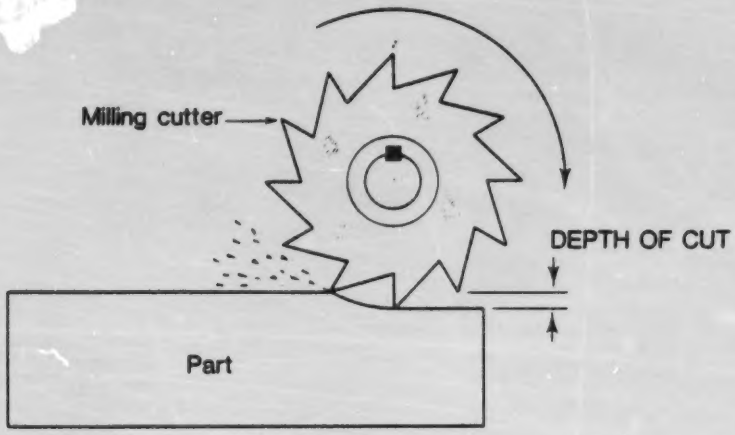
The machinist must set the correct RPM of the spindle to set up machine tools and to do machine operations.
The machinist uses his/her knowledge and experience to set the correct RPM on a machine tool to do a machine operation.

DEPTH OF CUT

The cutter of a machine tool cuts metal chips from a part.
The amount of metal that a cutter cuts from a part is called the DEPTH OF CUT.
Most of the time, the machinist measures the depth of cut in thousandths (.001, .002, .003, ...) of an inch.

On the horizontal mill, the milling cutter cuts metal chips from the part.

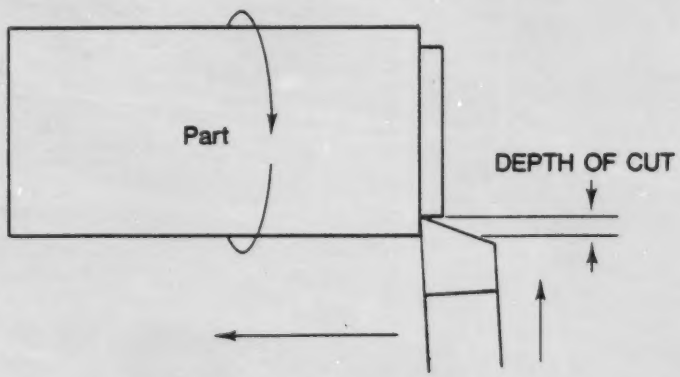
EXAMPLE C



In EXAMPLE C, the depth of cut is the amount of metal the milling cutter cuts from the part.
A depth of cut of .030" on the horizontal mill cuts .030" of metal from the part.

On the lathe, the tool bit cuts metal chips from the part.

EXAMPLE D



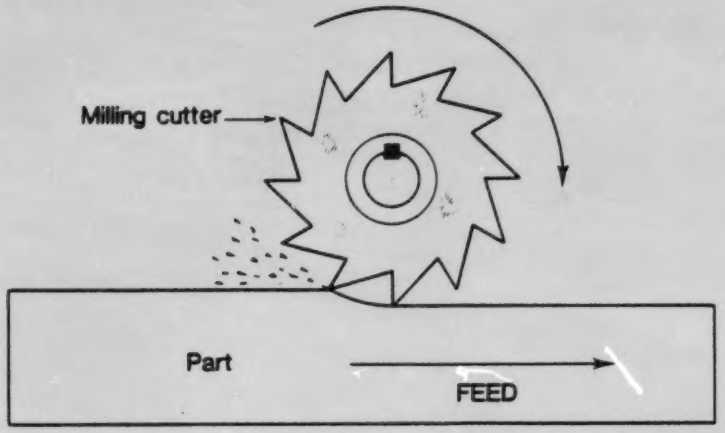
In EXAMPLE D, the depth of cut is the amount of metal the tool bit cuts from one side of the part.
A depth of cut of .010" on the lathe cuts .010" of metal from one side of the part.

The machinist must set the correct depth of cut to set up machine tools and to do machine operations.
The machinist uses his/her knowledge and experience to set the correct depth of cut on a machine tool to do a machine operation.

FEED

On some machine tools, like the horizontal mill, the machinist feeds (moves) the part into the cutter.
On these machine tools, moving the part into the cutter is called FEED.

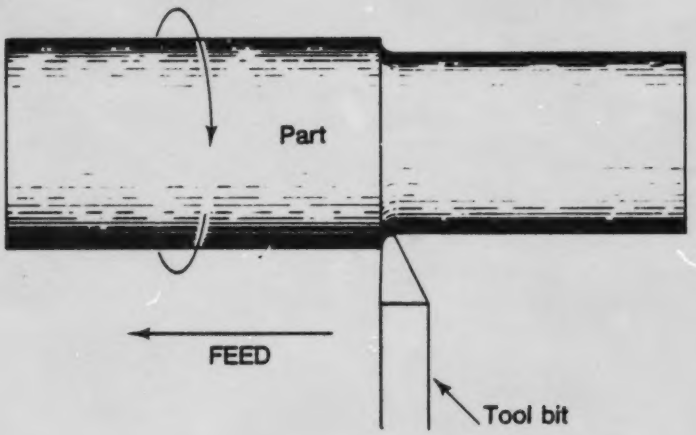
EXAMPLE E



In EXAMPLE E, the machinist feeds the part into the milling cutter on the horizontal mill.

On some machine tools, like the lathe, the machinist feeds (moves) the cutter into the part.
On these machine tools, moving the cutter into the part is called FEED.

EXAMPLE F



In EXAMPLE F, the machinist feeds the tool bit into the part on the lathe.

On the horizontal mill, the machinist uses his/her knowledge and experience to feed the part into the milling cutter.

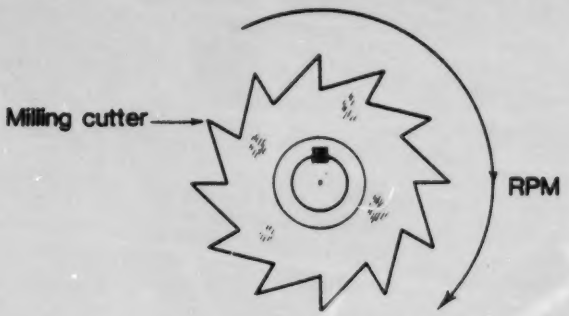
On the lathe, the machinist uses his/her knowledge and experience to feed the tool bit into the part.

RPM, DEPTH OF CUT, AND FEED

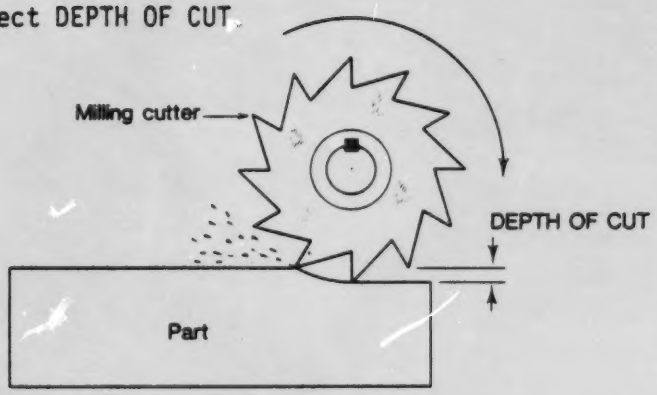
To do a machine operation on the horizontal mill, a machinist usually follows these steps:

STEP 1. Set the correct RPM of the spindle and the milling cutter.
STEP 2. Set the correct DEPTH OF CUT.
STEP 3. FEED the part into the milling cutter.

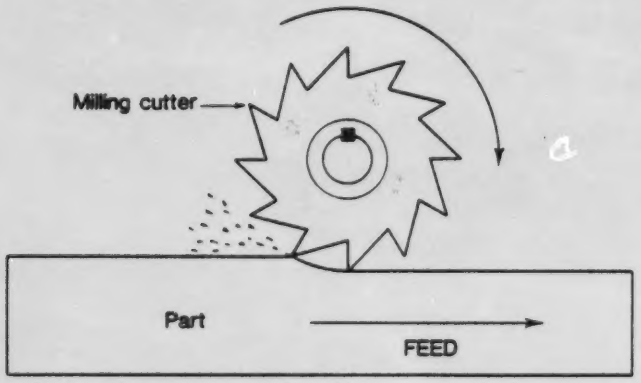
STEP 1. Set the correct RPM of the spindle and milling cutter.



STEP 2. Set the correct DEPTH OF CUT.



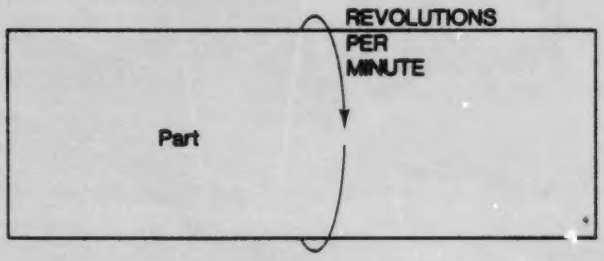
STEP 3. FEED the part into the milling cutter.



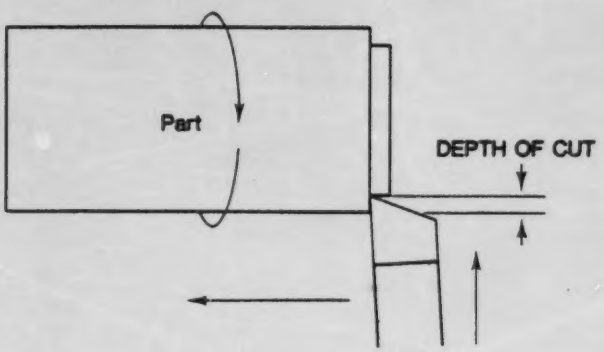
To do a machine operation on the lathe, a machinist usually follows these steps:

STEP 1. Set the correct RPM of the spindle and the part.
STEP 2. Set the correct DEPTH OF CUT.
STEP 3. FEED the tool bit into the part.

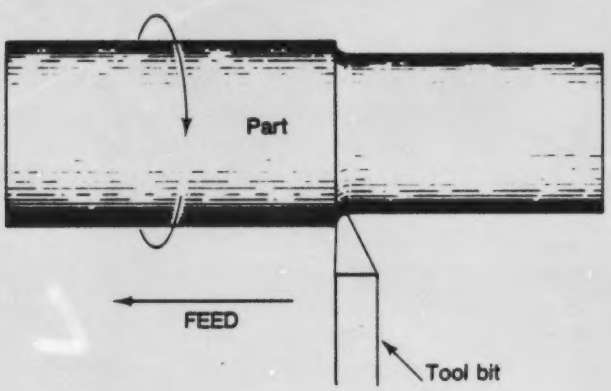
STEP 1. Set the correct RPM of the spindle and the part.



STEP 2. Set the correct DEPTH OF CUT.



STEP 3. FEED the tool bit into the part.



SUMMARY

To set up machine tools and to do machine operations on parts, a machinist must understand these factors:

1. REVOLUTIONS PER MINUTE (RPM)
2. DEPTH OF CUT
3. FEED

A machinist uses his/her knowledge and experience to set the correct revolutions per minute (RPM), depth of cut, and feed on a machine tool.

Revolutions per minute

Most machine tools have a spindle.
An electric motor and gears inside the machine tool revolve the spindle.
A machinist measures the speed of the spindle in REVOLUTIONS PER MINUTE (RPM).
The abbreviation for revolutions per minute is RPM.

On some machine tools, like the horizontal mill, the spindle revolves the cutter.
On these machine tools, when the spindle makes 1 revolution, the cutter also makes 1 revolution.
For example, on the horizontal mill, 150 RPM means the milling cutter makes 150 revolutions in one minute.

On some machine tools, like the lathe, the spindle revolves the part.
On these machine tools, when the spindle makes 1 revolution, the part also makes 1 revolution.
For example, on the lathe, 80 RPM means the part makes 80 revolutions in one minute.

Depth of cut

The cutter of a machine tool cuts metal chips from a part.
The amount of metal that a cutter cuts from a part is called the DEPTH OF CUT.
Most of the time, the machinist measures the depth of cut in thousandths (.001, .002, .003, ...) of an inch.

Feed

On some machine tools, like the horizontal mill, the machinist feeds (moves) the part into the cutter.
On these machine tools, moving the part into the cutter is called FEED.
On the horizontal mill, the machinist feeds the part into the milling cutter.

On some machine tools, like the lathe, the machinist feeds (moves) the cutter into the part.
On these machine tools, moving the cutter into the part is called FEED.
On the lathe, the machinist feeds the tool bit into the part.

Machine Shop Fundamentals

4A

UNIT 4: Measurement

LESSON 4A: Introduction to Measurement

OBJECTIVES:

1. The student will write the correct definition of measurement.
2. The student will write the reason why a machinist must make accurate measurements.
3. The student will choose the correct definition of the degree of accuracy.
4. The student will write the 2 main kinds of accuracy in the machine shop.
5. The student will choose the correct definition of semiprecision measurement.
6. The student will choose the smallest fraction of an inch on semiprecision measurement tools.
7. The student will write the correct fraction of an inch on a picture of a rule.
8. The student will choose the correct definition of precision measurement.
9. The student will choose the smallest decimal part on most precision measurement tools.

PROCEDURES:

1. Read the Objectives.
2. Read the Lesson.
3. Watch the Slide Show.
4. Do the Study Questions.
5. Do the Worksheets.
6. Do the Review Questions.
7. Do the Self-Test.

REFERENCES:

INTRODUCTION

What is measurement?

Finding the sizes of a part is called measurement.

The machinist measures a part to find the sizes of the part.
He/she uses MEASUREMENT TOOLS to measure parts.
Some textbooks call them measurement instruments or measurement devices.

A machinist uses machine tools to make parts.
The machinist must make accurate parts.
Accurate parts fit together with other parts.
Inaccurate parts do not fit together with other parts.
Inaccurate parts are called SCRAP.

Why must a machinist make accurate measurements?

A machinist must make accurate measurements to make accurate parts.

A machinist measures parts (technical meaning) in inches and parts (general meaning) of an inch.

Remember, a part (technical meaning) is the piece of material on which the machinist does various machine operations.
A part (general meaning) is a segment or portion of a whole thing, for example, a segment or portion of an inch.

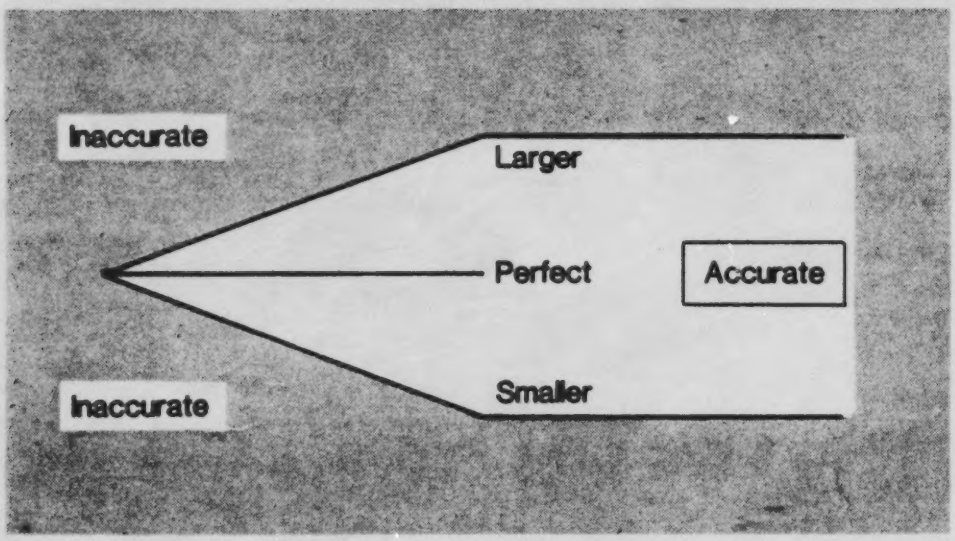
A machinist uses fractions and decimal numbers to measure parts.

ACCURACY

Machines are not perfect.
Measurement tools are not perfect.
A machinist cannot make a perfect measurement on every part.

All parts need accurate measurements.
But some parts need very accurate measurements.

There are degrees of accuracy.
A measurement can be accurate even when it is not perfect.



An accurate measurement can be a little larger than the perfect measurement.
An accurate measurement can be a little smaller than the perfect measurement.

The degree of accuracy is the amount an accurate measurement can be larger or smaller than the perfect measurement.

In the machine shop there are 2 main kinds of accuracy:

1. Semiprecision accuracy
2. Precision accuracy

For semiprecision accuracy, the machinist uses SEMIPRECISION MEASUREMENT and SEMIPRECISION MEASUREMENT TOOLS.

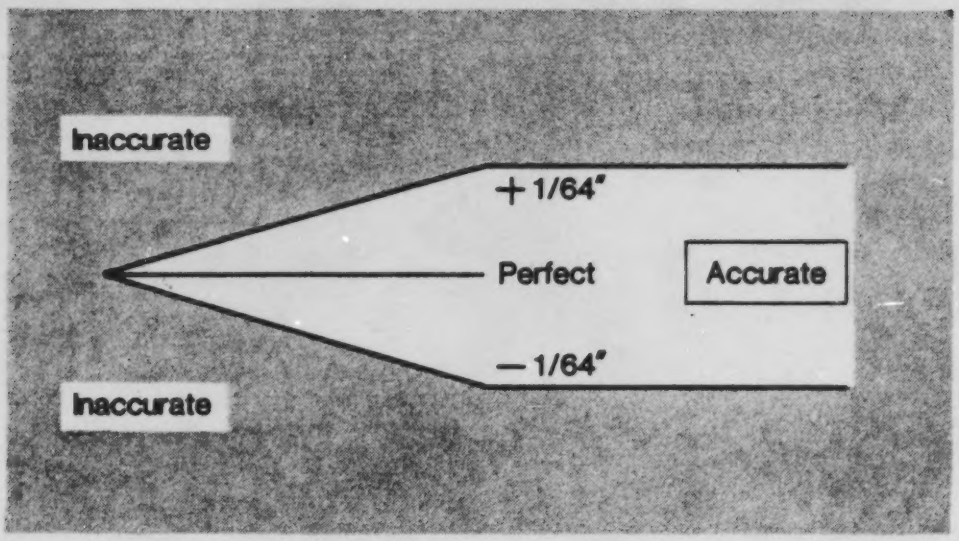
For precision accuracy, the machinist uses PRECISION MEASUREMENT and PRECISION MEASUREMENT TOOLS.

SEMIPRECISION MEASUREMENT

Semiprecision measurement is accurate to within $\frac{1}{64}$ of an inch larger than the perfect measurement, or $\frac{1}{64}$ of an inch smaller than the perfect measurement.

The machinist writes $+\frac{1}{64}$" to show $\frac{1}{64}$ of an inch larger than the perfect measurement.

The machinist writes $-\frac{1}{64}$" to show $\frac{1}{64}$ of an inch smaller than the perfect measurement.



A semiprecision measurement can be $+\frac{1}{64}$" or $-\frac{1}{64}$" and still be accurate.

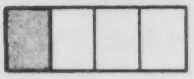
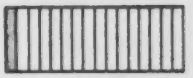
In semiprecision measurement, the machinist measures parts in inches and fractions of an inch.

In the machine shop, the machinist reads these fractions of an inch:

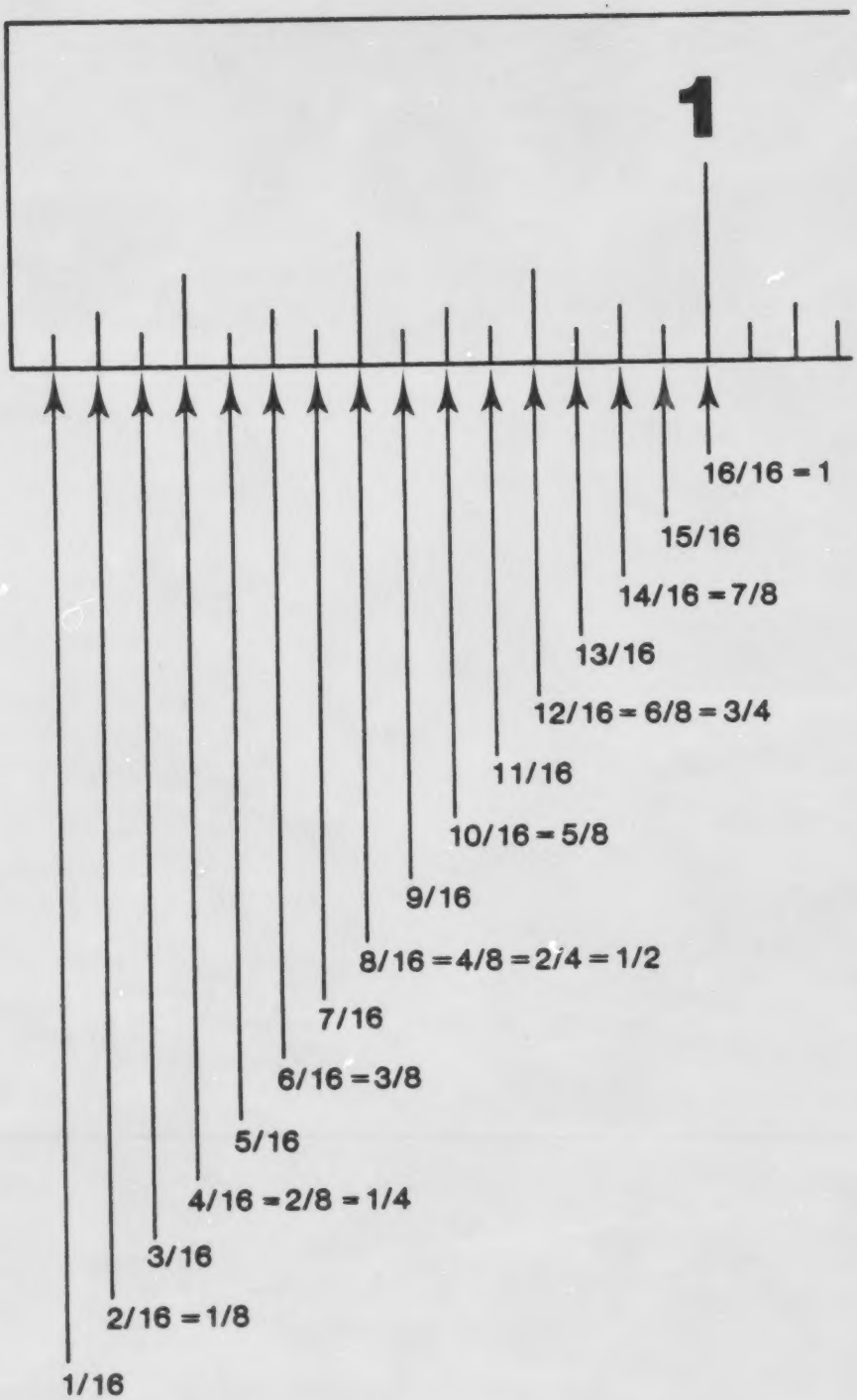
Halves	$\frac{1}{2}$,			$\frac{2}{2}$	$\frac{2}{2}$ = 1 inch
Fourths or Quarters	$\frac{1}{4}$,	...,	$\frac{3}{4}$,	$\frac{4}{4}$	$\frac{4}{4}$ = 1 inch
Eighths	$\frac{1}{8}$,	...,	$\frac{7}{8}$,	$\frac{8}{8}$	$\frac{8}{8}$ = 1 inch
Sixteenths	$\frac{1}{16}$,	...,	$\frac{15}{16}$,	$\frac{16}{16}$	$\frac{16}{16}$ = 1 inch
Thirty-seconds	$\frac{1}{32}$,	...,	$\frac{31}{32}$,	$\frac{32}{32}$	$\frac{32}{32}$ = 1 inch
Sixty-fourths	$\frac{1}{64}$,	...,	$\frac{63}{64}$,	$\frac{64}{64}$	$\frac{64}{64}$ = 1 inch

In semiprecision measurement, $\frac{1}{64}$ of an inch is the smallest fraction on the semiprecision measurement tools.

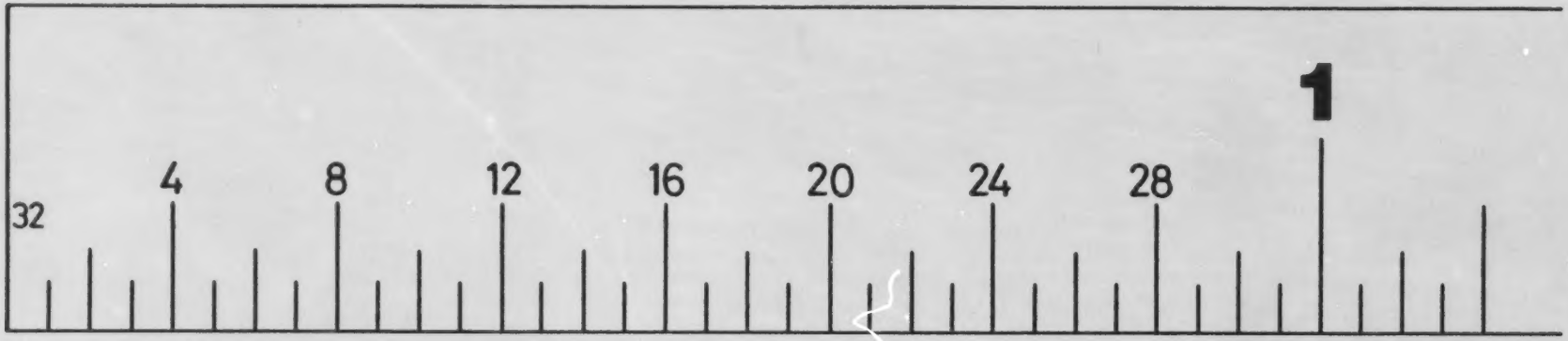
Semiprecision measurement tools divide an inch into halves, fourths, eighths, sixteenths, thirty-seconds, and sixty-fourths.

Halves	Fourths or Quarters	Eighths	Sixteenths
			
			1/16
		1/8	2/16
			3/16
	1/4	2/8	4/16
			5/16
		3/8	6/16
			7/16
1/2	2/4	4/8	8/16
			9/16
		5/8	10/16
			11/16
	3/4	6/8	12/16
			13/16
		7/8	14/16
			15/16

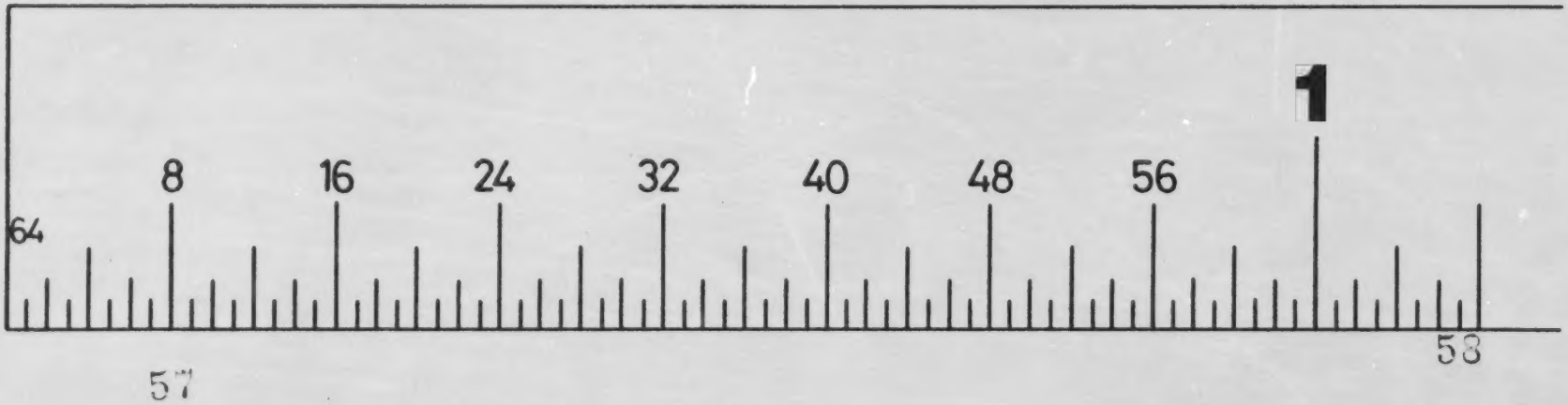
Reading Sixteenths



Reading Thirty-seconds



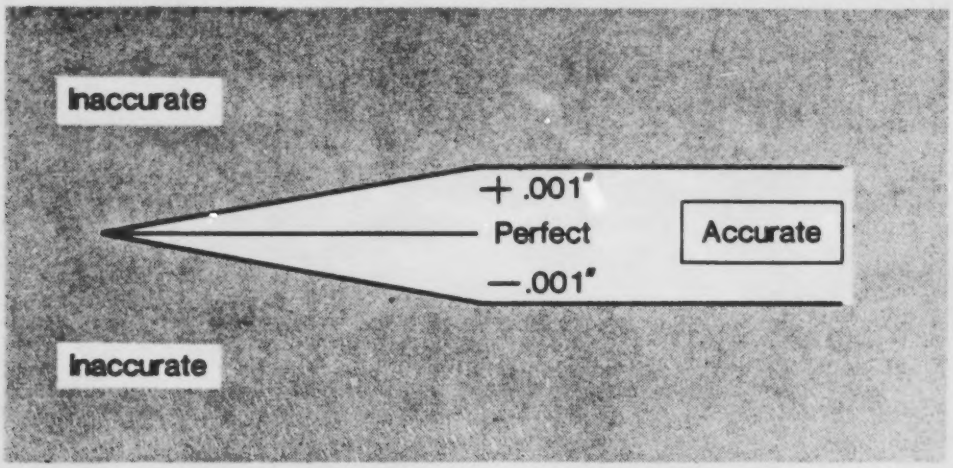
Reading Sixty-fourths



PRECISION MEASUREMENT

Precision measurement is accurate to within .001 of an inch or smaller.
Remember, $.001 = \frac{1}{1000}$

The precision measurement can be .001 of an inch larger than the perfect measurement, or .001 of an inch smaller than the perfect measurement.
The machinist writes + .001" to show .001 of an inch larger than the perfect measurement.
The machinist writes - .001" to show .001 of an inch smaller than the perfect measurement.



A precision measurement can be + .001" or - .001" and still be accurate.

In precision measurement, the machinist measures parts in inches and decimal parts of an inch.
In the machine shop, the machinist reads these decimal parts:

.001, .002, .003, ... , .999, 1.000

1.000" = 1 inch

In precision measurement, .001 of an inch is the smallest decimal part on most precision measurement tools.
On some precision measurement tools .0001 of an inch is the smallest decimal part.
Remember, $.0001 = \frac{1}{10000}$

Precision measurement tools divide an inch into thousandths (.001, .002, ...) or ten-thousandths (.0001, .0002, ...).

SUMMARY

All parts need accurate measurement.
But some parts need very accurate measurements.

In the machine shop, there are 2 main kinds of accuracy:

1. Semiprecision accuracy
2. Precision accuracy

For semiprecision accuracy, the machinist uses semiprecision measurement and semiprecision measurement tools.
For precision accuracy, the machinist uses precision measurement and precision measurement tools.

Semiprecision measurement is accurate to within $+\frac{1}{64}$" or $-\frac{1}{64}$"

Precision measurement is accurate to within + .001" or - .001"

To compare, $\frac{1}{64}$" is a little more than .015"

$\frac{1}{64} = .0156$

Precision measurement measures smaller parts of an inch than semiprecision measurement measures.
Precision measurement has a higher degree of accuracy than semiprecision measurement has.
In other words, precision measurement is more accurate than semiprecision measurement is.

The blueprint tells the machinist to use semiprecision measurement or to use precision measurement to measure the sizes of a part.

In the next lessons, you will learn how to use semiprecision measurement tools and precision measurement tools.

Machine Shop Fundamentals

4B

UNIT 4: Measurement

LESSON 4B: Semiprecision Measurement

OBJECTIVES:

1. The student will write the correct definition of semiprecision measurement.
2. The student will match the name of a semiprecision measurement tool to a picture of that measurement tool.
3. The student will match the name of a semiprecision measurement tool to a description of that measurement tool.
4. The student will choose the correct rules for the care of measurement tools.

PROCEDURES:

1. Read the Objectives.
2. Read the Lesson.
3. Watch the Slide Show.
4. Watch the teacher's Demonstration.
5. Do the Study Questions.
6. Do the Worksheets.
7. Do the Review Questions.
8. Do the Self-Test.

REFERENCES:

INTRODUCTION

For semiprecision accuracy, the machinist uses semiprecision measurement and semiprecision measurement tools.

What is semiprecision measurement?

SEMIPRECISION MEASUREMENT is the measurement of parts to within $\frac{1}{64}$ of an inch.

Semiprecision measurement is accurate to $+\frac{1}{64}$ or $-\frac{1}{64}$ of an inch.

The machinist uses semiprecision measurement tools to measure these fractions: halves, fourths, eighths, sixteenths, thirty-seconds, and sixty-fourths.

SEMIPRECISION MEASUREMENT TOOLS

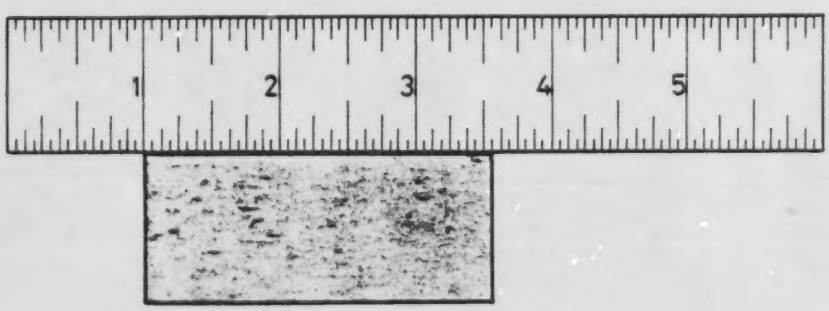
The machinist uses semiprecision measurement tools to make semiprecision measurements.

In this unit, you will learn to measure parts with these semiprecision measurement tools:

1. The 6" rule
2. The hook rule
3. The depth rule
4. The combination square
5. The inside caliper
6. The outside caliper
7. The tape rule
8. The short-length rule and holder
9. The bevel protractor

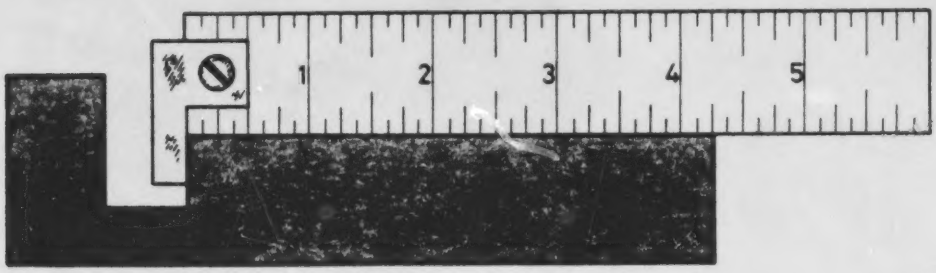
1. THE 6" RULE

The most common semiprecision measurement tool is the 6" RULE. The machinist reads measurements on the 6" rule.



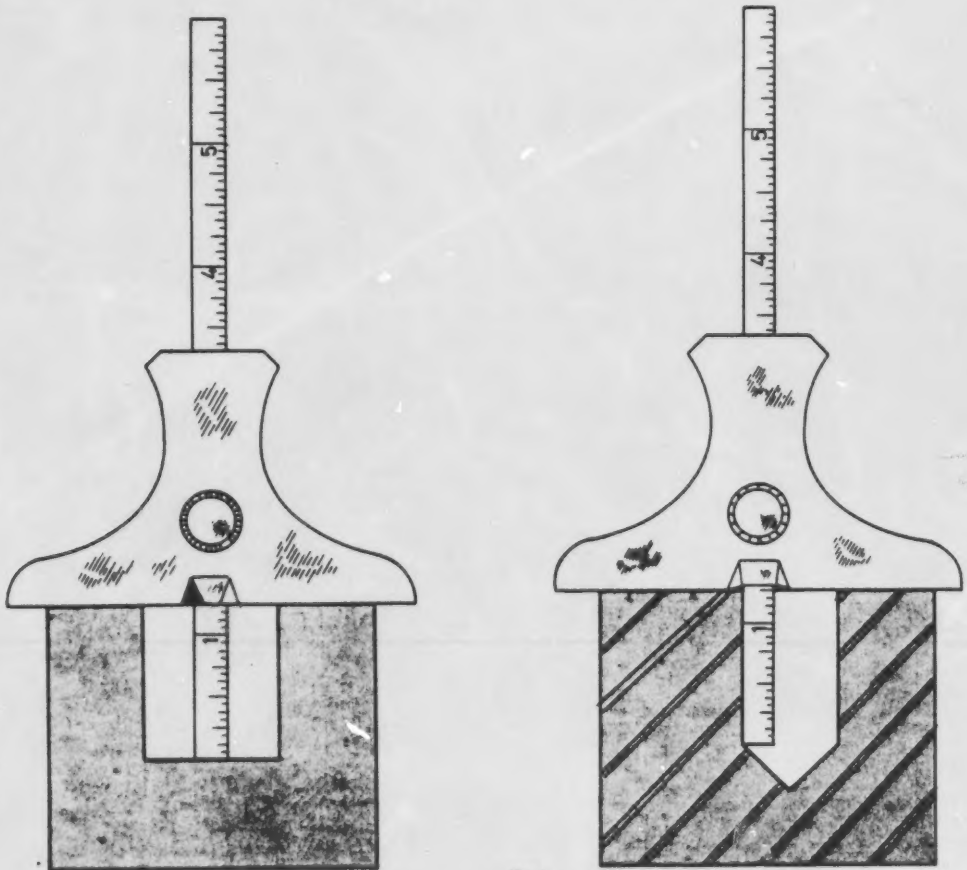
2. THE HOOK RULE

The machinist also uses the HOOK RULE to measure parts.
He/she reads the hook rule like a 6" rule.



3. THE DEPTH RULE

The machinist uses the DEPTH RULE to measure the depth of slots in parts and the depth of blind holes.
A blind hole does not go all the way through a part.
The machinist reads the depth rule like a 6" rule.

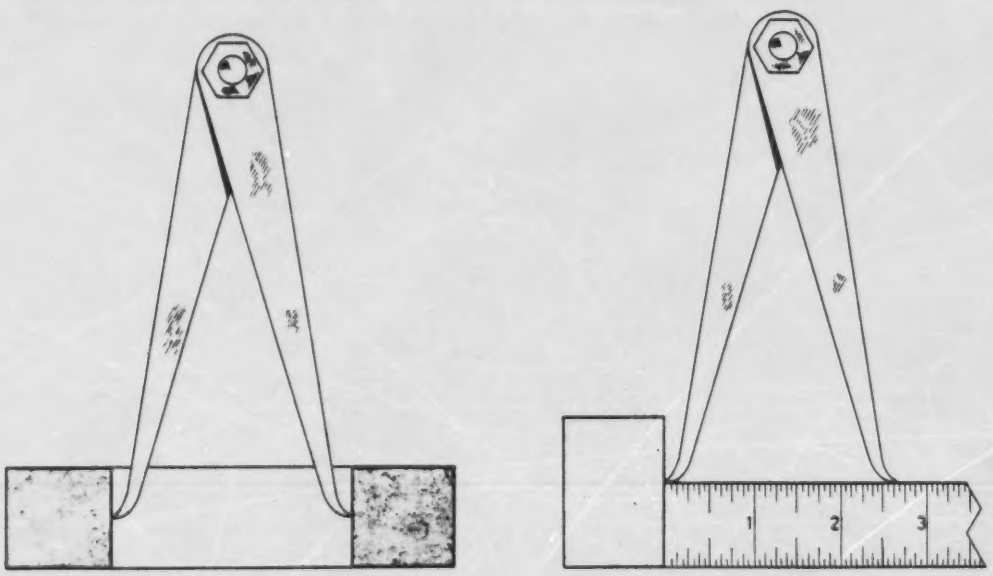


4. THE COMBINATION SQUARE

The machinist uses the COMBINATION SQUARE like a 6" rule or a depth rule to measure parts.
He/she reads the combination square like a 6" rule.

5. THE INSIDE CALIPER

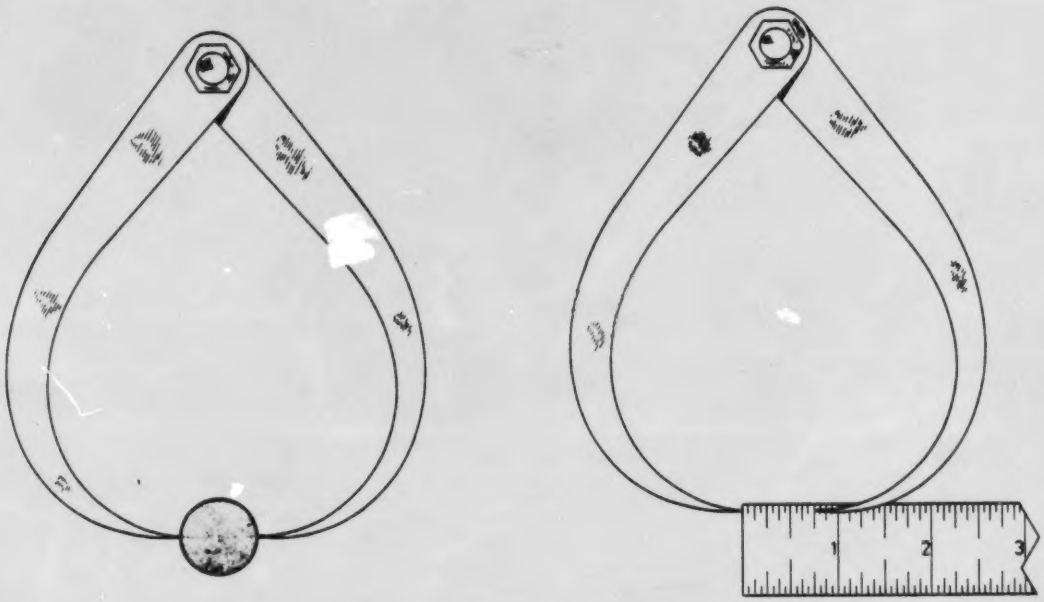
Sometimes the machinist must measure the inside diameter of a hole in a part, but he/she cannot use only a 6" rule.
Then, he uses an INSIDE CALIPER and a 6" rule.



First, the machinist adjusts the inside caliper to the inside diameter of the hole in the part.
Next, he/she holds the inside caliper against a 6" rule.
Then, he/she reads the measurement on the 6" rule.

6. THE OUTSIDE CALIPER

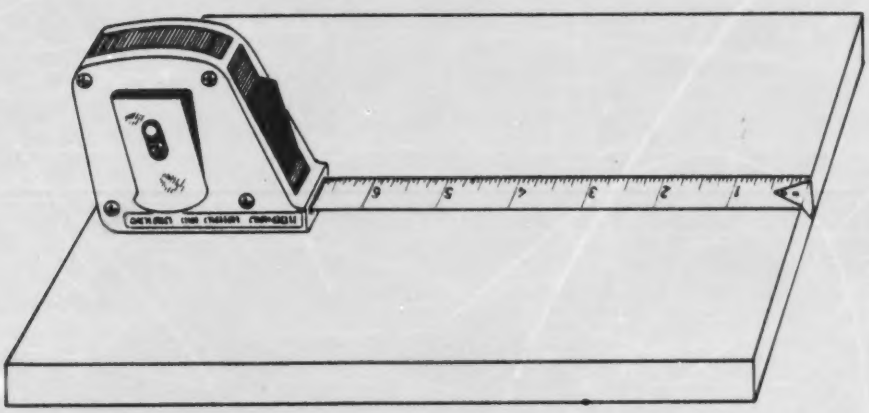
Sometimes the machinist must measure the outside diameter of a part, but he/she cannot use only a 6" rule.
Then, he/she uses an OUTSIDE CALIPER and a 6" rule.



First, the machinist adjusts the outside caliper to the outside diameter of the part.
Next, he/she holds the outside caliper against the 6" rule.
Then, he/she reads the measurement on the 6" rule.

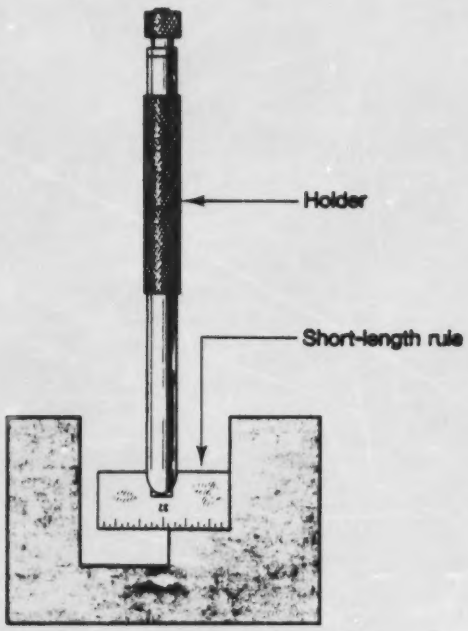
7. THE TAPE RULE

The machinist uses the TAPE RULE to measure long pieces of stock.
A tape rule is accurate to $+\frac{1}{16}"$ or $-\frac{1}{16}"$



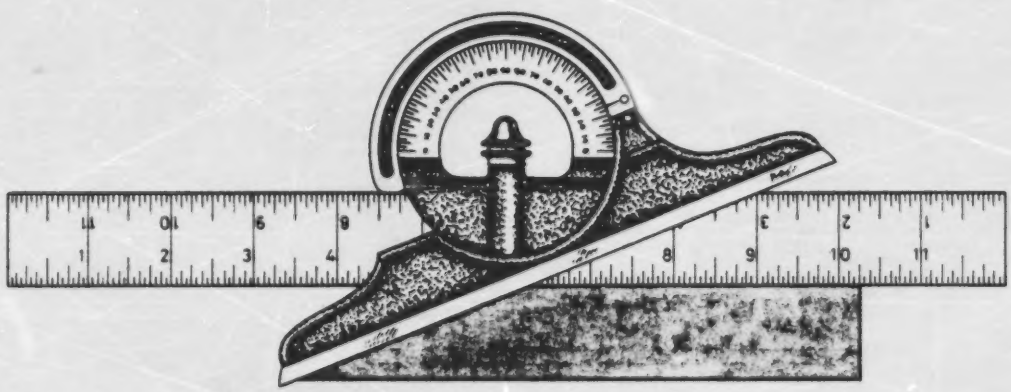
8. THE SHORT-LENGTH RULE and THE HOLDER

Sometimes the machinist must measure a small dimension (size) on a part, but he/she cannot use a 6" rule because the 6" rule is too big.
Then he/she uses a SHORT-LENGTH RULE and HOLDER.
The holder holds the short-length rule.



9. THE BEVEL PROTRACTOR

The machinist uses the BEVEL PROTRACTOR to measure angles on parts.
An angle on a part is called a bevel.
A machinist measures angles in degrees.



CARE OF MEASUREMENT TOOLS

These rules will help you make accurate measurements and accurate parts without damage to measurement tools.

Employers will want you to use measurement tools carefully and correctly.

GENERAL RULES

1. Do not drop measurement tools.

2. Do not carry measurement tools with other tools.
   You will drop or scratch the measurement tools.

3. Do not put measurement tools in a pile of tools.

4. Do not try to measure moving parts.

5. Do not remove rust or stains on measurement tools with abrasive cloth.

6. Wipe off measurement tools and then put the measurement tools away.

CARE OF MEASUREMENT TOOLS

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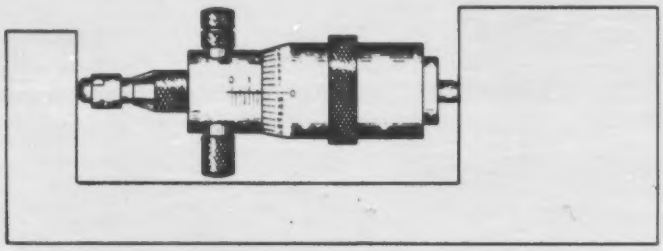
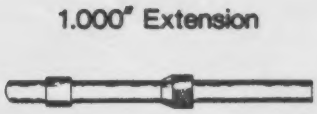
2. THE INSIDE MICROMETER

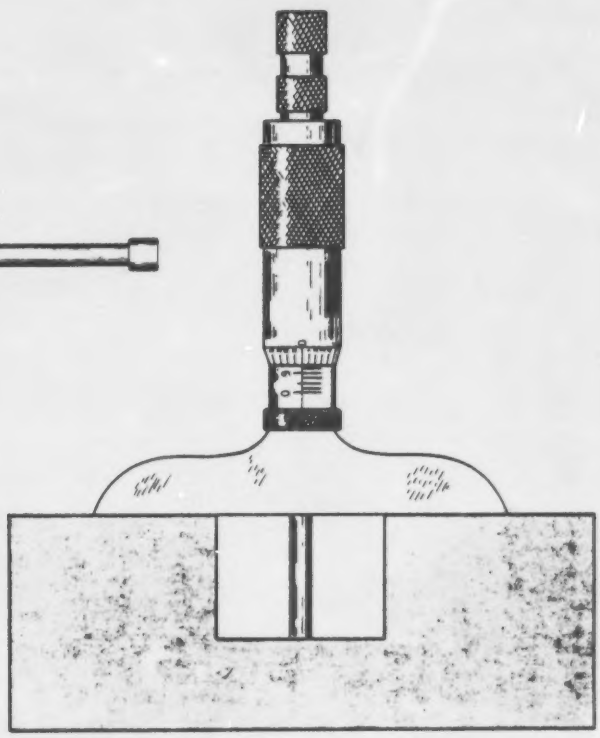




The machinist uses the inside micrometer to measure inside dimensions of parts.
He/she measures the inside diameter of a hole and the width of a slot.
He/she reads the measurements on the inside micrometer.

The machinist uses this inside micrometer to measure inside dimensions from 1.000" to 2.000"
He/she uses a 1.000" extension, 2.000" extension, 3.000" extension, etc., to measure larger inside dimensions.

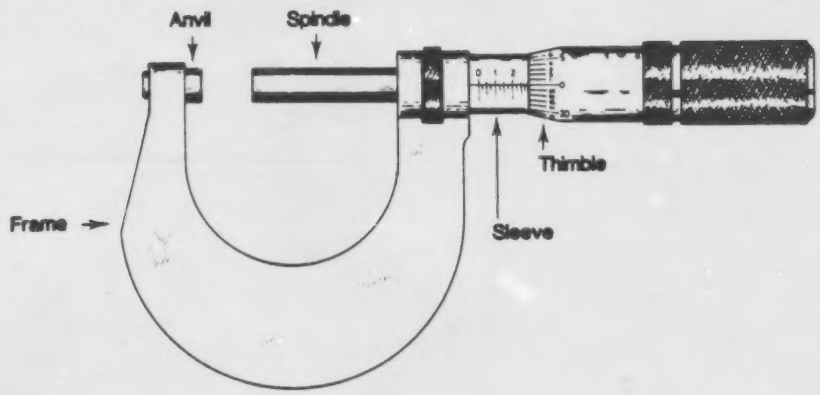
3. THE DEPTH MICROMETER



The machinist uses the depth micrometer like a depth rule to measure dimensions.
He/she measures the depth of a slot in a part and the depth of a blind hole in a part.
He/she reads the measurements on the depth micrometer.

He/she uses this depth micrometer to measure dimensions from 0.000" to 1.000"
He/she uses a 1.000" extension, 2.000" extension, 3.000" extension, etc., to measure larger dimensions.

PARTS OF THE MICROMETER



The machinist measures parts between the ANVIL and the SPINDLE.
He/she must keep the anvil and spindle very clean to make accurate measurements.
He/she reads 2 measurements on the SLEEVE.

a. He/she reads .100", .200", .300", ..., .900" on the sleeve.
b. He/she also reads .025", .050", and .075" on the sleeve.

He/she reads 1 measurement on the THIMBLE.

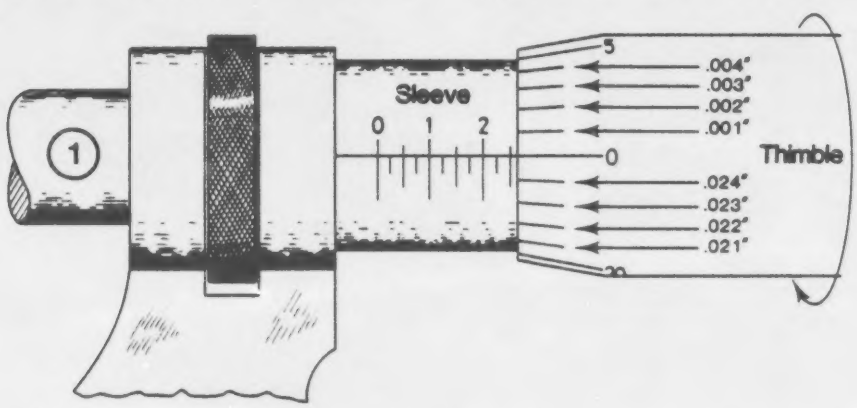
c. He/she reads .001" to .024" on the thimble.

The FRAME holds the anvil, spindle, sleeve, and thimble.

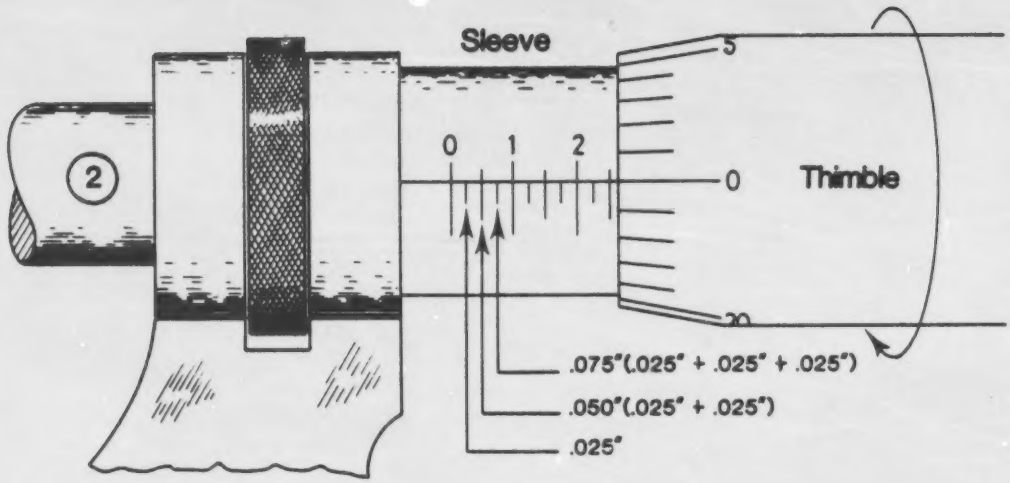
READING THE OUTSIDE AND INSIDE MICROMETERS

The machinist reads thousandths of an inch (.001") on the outside micrometer and inside micrometer.

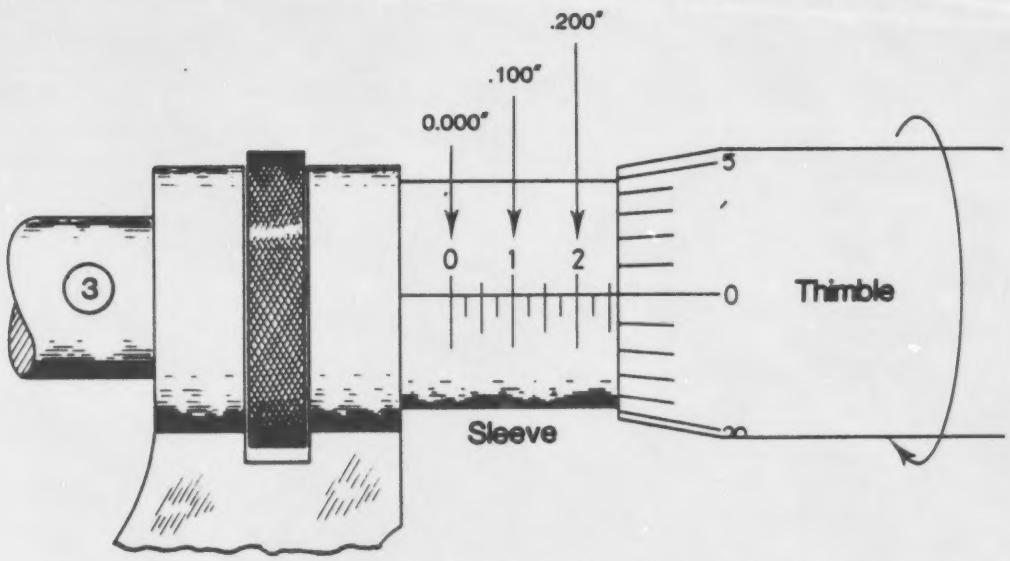
When the machinist reads a micrometer, he/she can think that 1.000" equals 1000 pennies. 1 penny = .001"
He/she counts the pennies in 3 ways.
He/she reads the thousandths (.001") on a micrometer in 3 ways.



The machinist counts the lines on the thimble as 1 to 24 pennies.
He/she reads the lines on the thimble as .001" to .024"



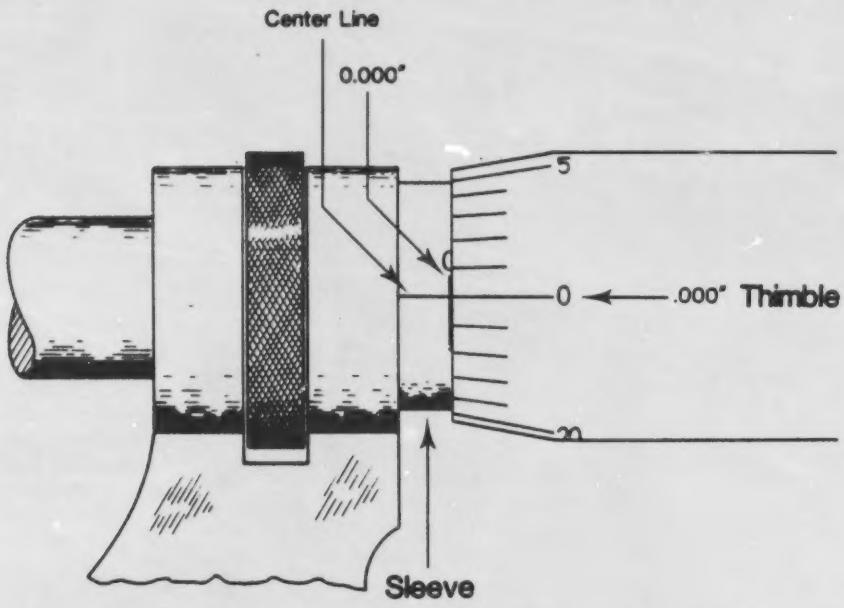
The machinist counts each small line without a number on the sleeve as 25 pennies.
He/she reads each small line without a number on the sleeve as .025"



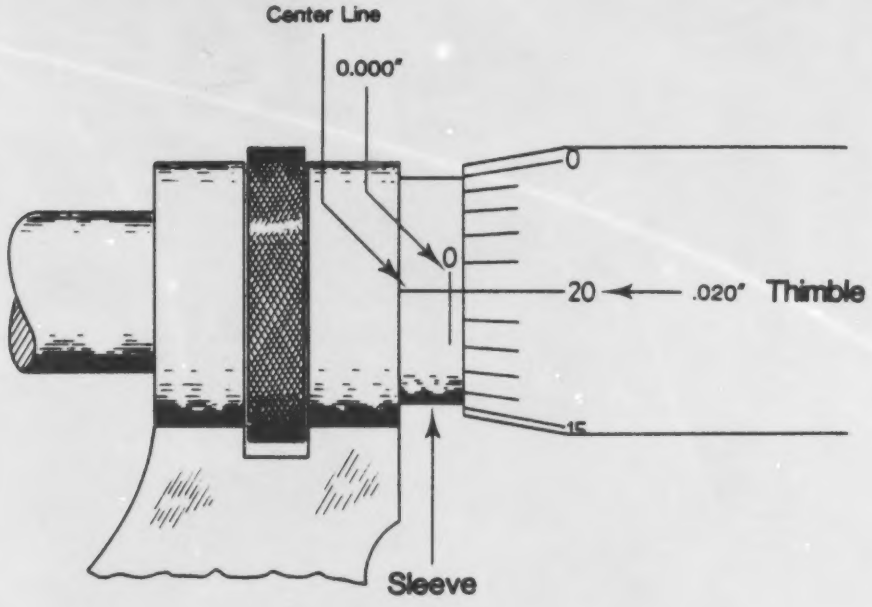
The machinist counts each line with a number (1 to 9) on the sleeve as 100 pennies.
He/she reads each line with a number (1 to 9) on the sleeve as .100"

Last, the machinist adds the pennies.
Last, the machinist adds the thousandths of an inch (.001")

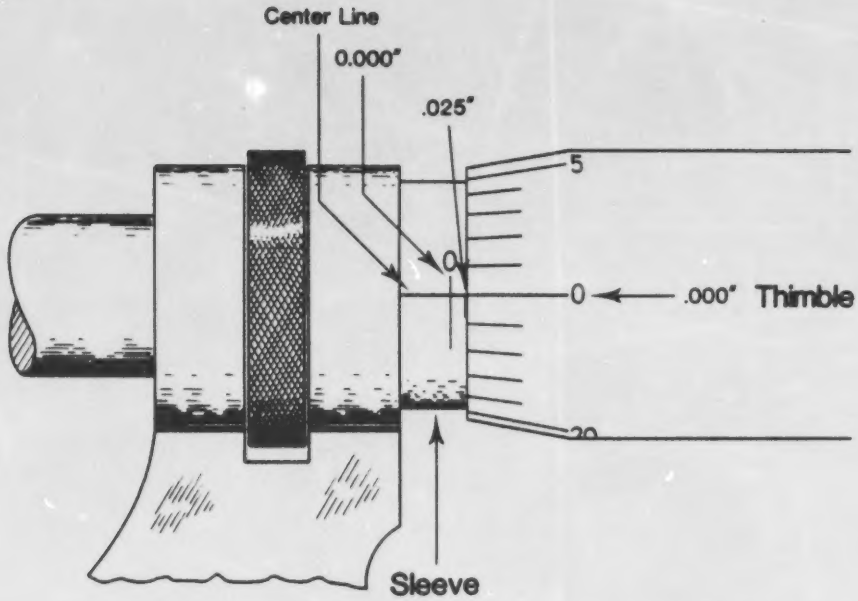
You will study the steps to read the outside micrometer and inside micrometer in the next pages.



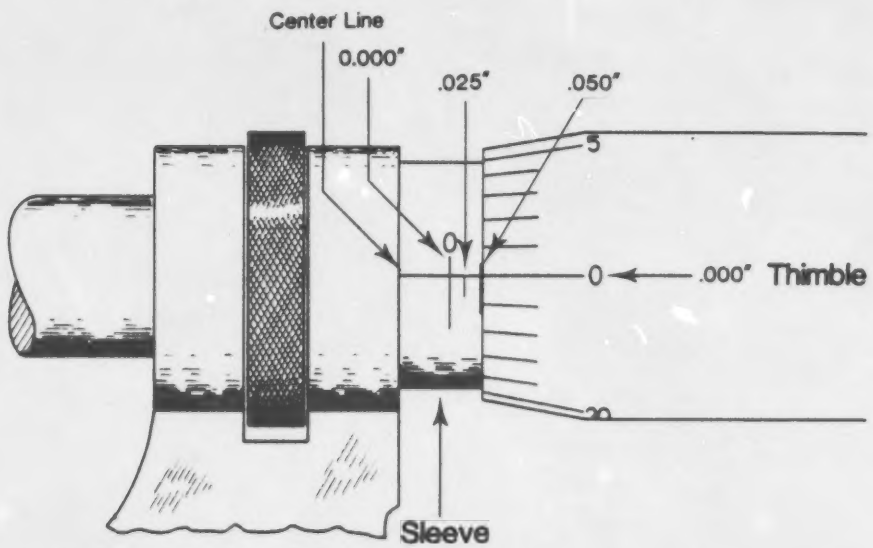
This micrometer reading is 0.000"
The edge of the thimble is on the 0.000" line of the sleeve.
The .000" line on the thimble lines up with the center line on the sleeve.



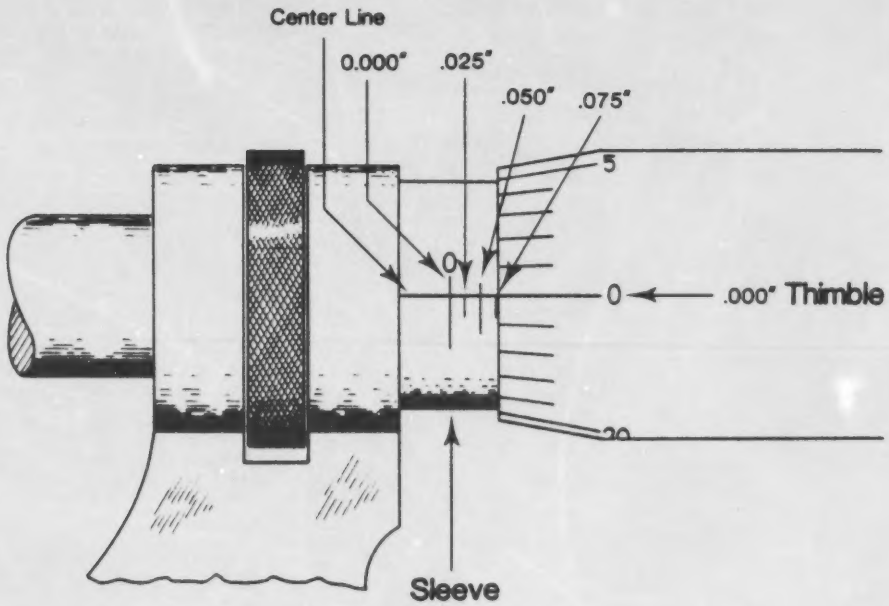
This micrometer reading is .020"
The edge of the thimble is not on the 0.000" line of the sleeve.
The .020" line on the thimble lines up with the center line on the sleeve.



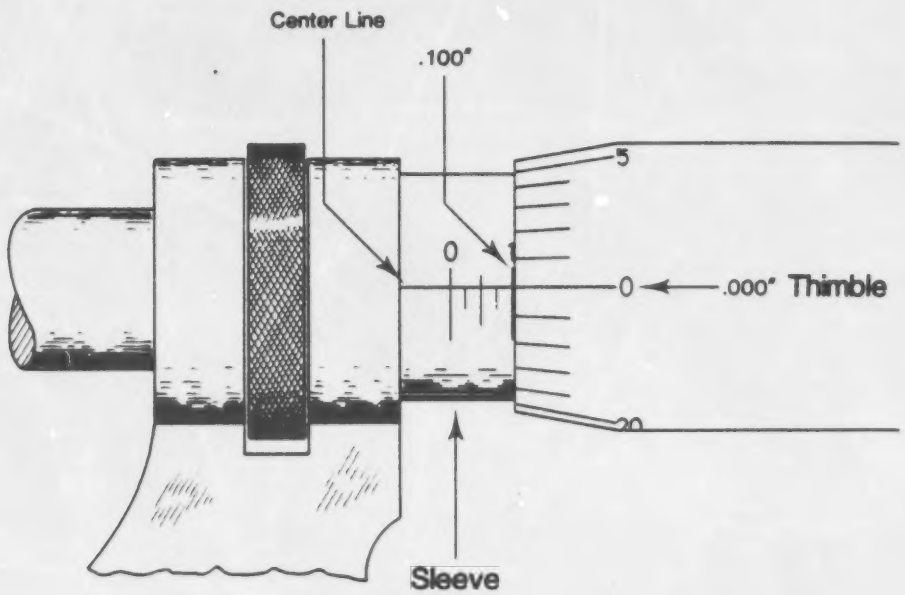
This micrometer reading is .025"
The edge of the thimble is on the .025" line on the sleeve.
The machinist cannot see all of the .025" line on the sleeve.
But, he/she can see the micrometer reading is not 0.000"
The .000" line on the thimble lines up with the center line on the sleeve.
The micrometer reading must be .025"



This micrometer reading is .050"
The edge of the thimble is on the .050" line on the sleeve.
The machinist cannot see all of the .050" line on the sleeve.
But, he/she can see the micrometer reading is not .025"
The .000" line on the thimble lines up with the center line on the sleeve.
The micrometer reading must be .050"

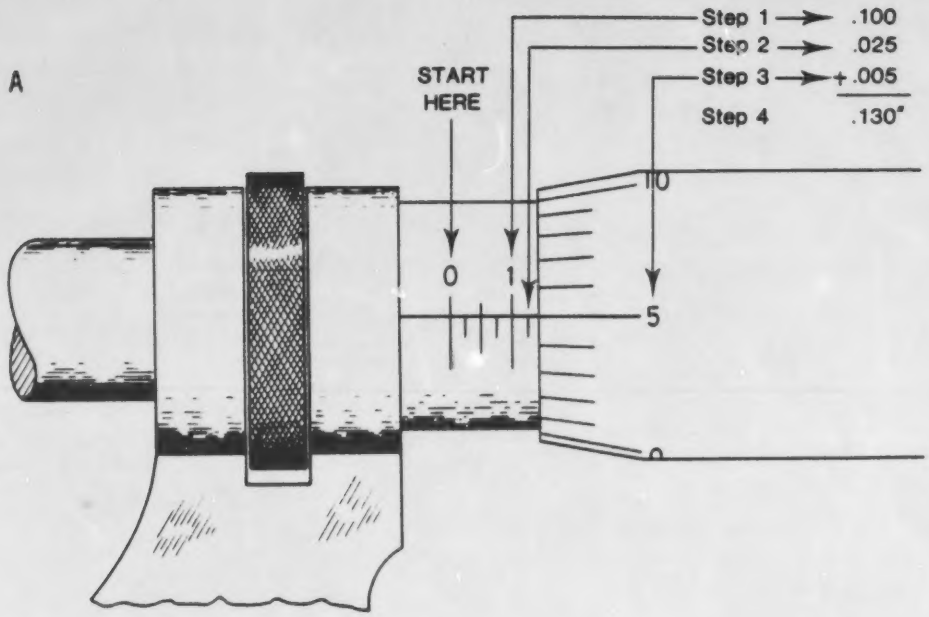


This micrometer reading is .075"
The edge of the thimble is on the .075" line on the sleeve.
The machinist cannot see all of the .075" line on the sleeve.
But, he/she can see the micrometer reading is not .050"
The .000" line on the thimble lines up with the center line on the sleeve.
The micrometer reading must be .075"



This micrometer reading is .100"
The edge of the thimble is on the .100" line on the sleeve.
The machinist cannot see all of the .100" line on the sleeve.
The .000" line on the thimble lines up with the center line or the sleeve.
The reading must be .100"

EXAMPLE A



The machinist always starts at 0.000" or the left side of the sleeve. He/she reads the outside micrometer and the inside micrometer from left to right (from the sleeve to the thimble).

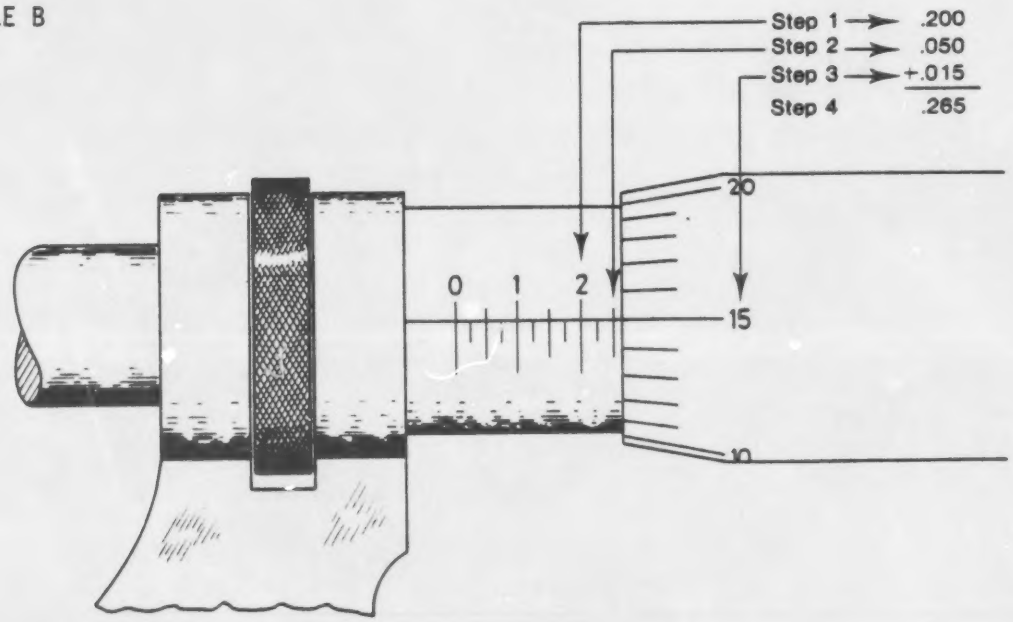
STEP 1. Read the .100", .200", .300", ..., .900" line on the sleeve.

STEP 2. Read the .025", .050", or .075" line on the sleeve.

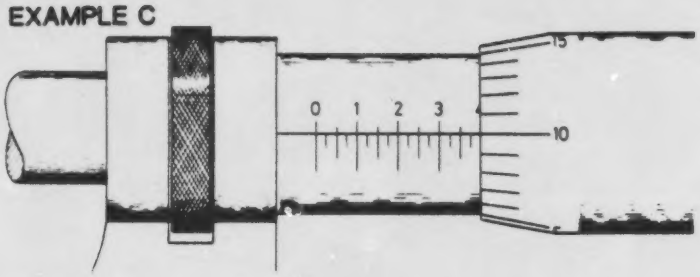
STEP 3. Read the .001", .002", .003", ..., .024" line on the thimble.

STEP 4. Add the readings from Step 1, Step 2, and Step 3. This is the dimension of the part.

EXAMPLE B



EXAMPLE C



STEP 1
STEP 2
STEP 3 _____
STEP 4

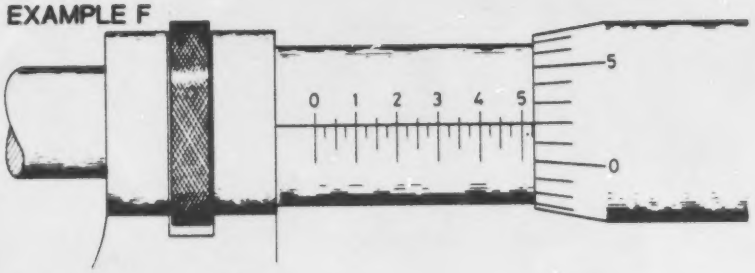
EXAMPLE D

STEP 1
STEP 2
STEP 3 _____
STEP 4

EXAMPLE E

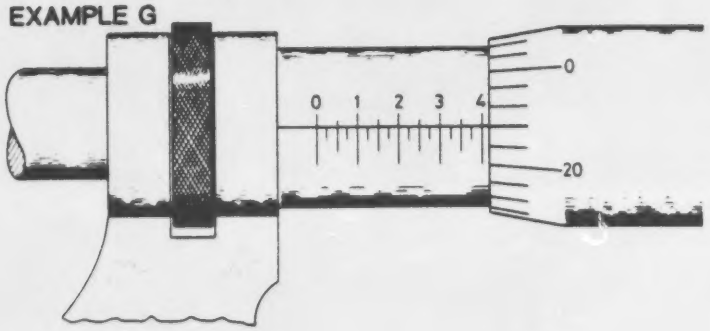
STEP 1
STEP 2
STEP 3 _____
STEP 4

EXAMPLE F



STEP 1
STEP 2
STEP 3 _____
STEP 4

EXAMPLE G



STEP 1
STEP 2
STEP 3 _____
STEP 4

Look on page 11 for the correct readings.

Machine Shop Fundamentals

4C

UNIT 4: Measurement

LESSON 4C: Precision Measurement with Micrometers

OBJECTIVES:

1. The student will write the correct definition of precision measurement.
2. The student will match the outside micrometer, the inside micrometer, and the depth micrometer to a description of that measurement tool.
3. The student will match the names of the parts of a micrometer to a picture of a micrometer.
4. The student will write the steps to read a micrometer.
5. The student will write the correct micrometer reading from a picture of a micrometer reading.
6. The student will choose the correct rules for the care of micrometers.

PROCEDURES:

1. Read the Objectives.
2. Read the Lesson.
3. Watch the Slide Show.
4. Watch the teacher's Demonstration.
5. Do the Study Questions.
6. Do the Worksheets.
7. Do the Review Questions.
8. Do the Self-Test.

REFERENCES:

INTRODUCTION

For precision accuracy, the machinist uses precision measurement and precision measurement tools.

What is precision measurement?

PRECISION MEASUREMENT is the measurement of parts to within .001 of an inch or smaller.

The machinist uses precision measurement tools to measure thousandths (.001, .002, .003, ...) of an inch and ten-thousandths (.0001, .0002, .0003, ...) of an inch.

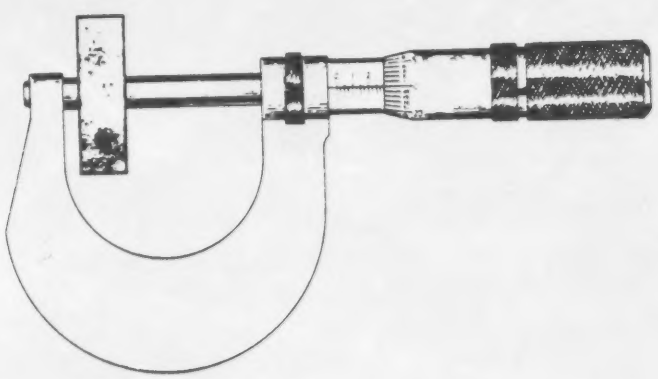
MICROMETERS

The machinist uses precision measurement tools to make precision measurements. In Lesson 4C, you will learn to measure parts with these precision measurement tools:

1. The outside micrometer
2. The inside micrometer
3. The depth micrometer

There are many kinds and sizes of micrometers.

1. THE OUTSIDE MICROMETER

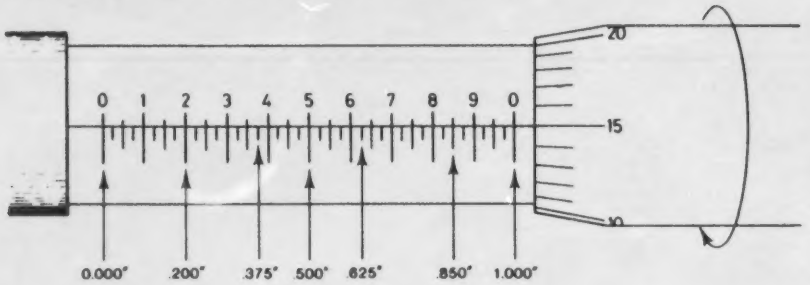


The machinist uses the outside micrometer to measure the outside dimensions of parts.
On round (cylindrical) parts, he/she measures the diameter and length.
On other parts, he/she measures the length, width, and thickness.
He/she reads measurements on the outside micrometer.

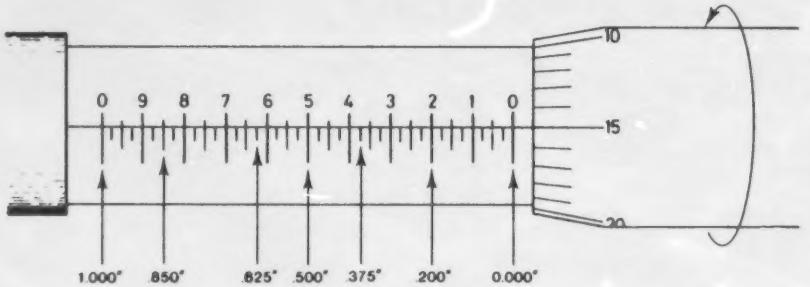
The machinist uses this 1" outside micrometer to measure dimensions from 0.000" to 1.000"
He/she uses a 2" outside micrometer to measure dimensions from 1.000" to 2.000"
He/she uses a 3" outside micrometer to measure dimensions from 2.000" to 3.000"
There are many other sizes of outside micrometers.

EXAMPLE C.	EXAMPLE D.	EXAMPLE E.	EXAMPLE F.	EXAMPLE G.
.300	.700	.900	.500	.400
.075	.050	.075	.025	.000
.010	.008	.017	.002	.022
.385"	.758"	.992"	.527"	.422"

THE SLEEVE OF THE OUTSIDE MICROMETER AND THE INSIDE MICROMETER



THE SLEEVE OF THE DEPTH MICROMETER



- Carefully study this page.
- Look at the difference between the sleeve of the outside and inside micrometer and the sleeve of the depth micrometer.
- Look at the difference between the thimble of the outside and inside micrometer and the thimble of the depth micrometer.

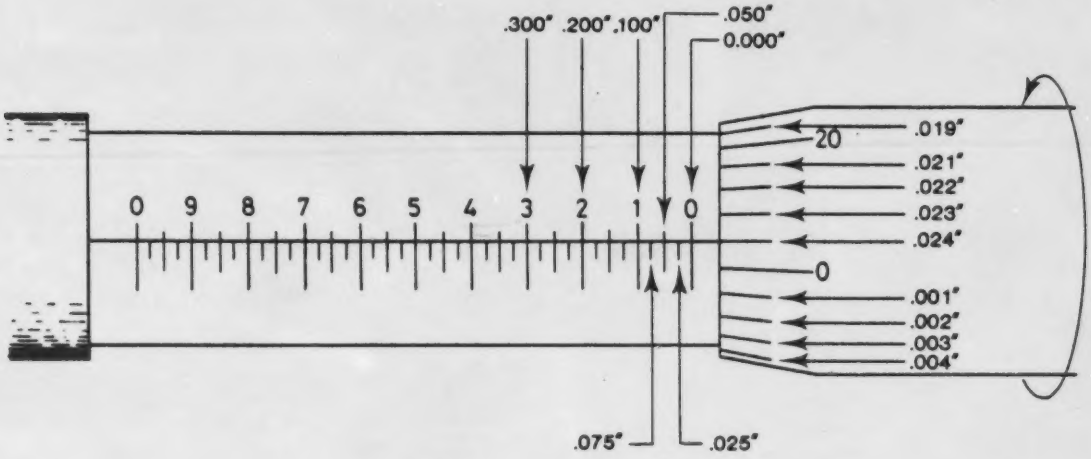
80

73

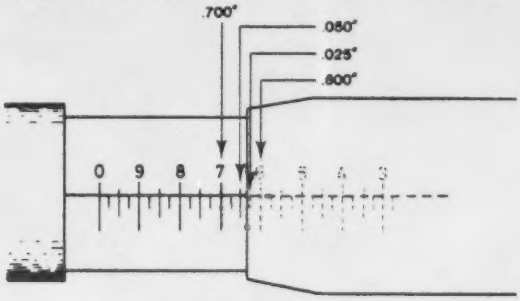
4C

READING THE DEPTH MICROMETER

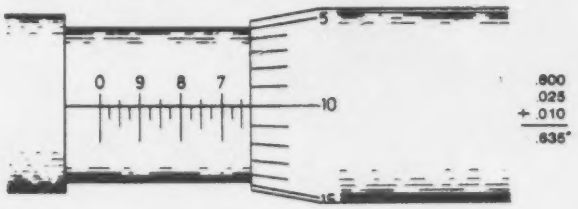
The machinist reads thousandths of an inch (.001") on the depth micrometer.



The machinist reads .100", .200", .300", ..., .900" on the sleeve.
He/she also reads .025", .050", and .075" on the sleeve.
He/she reads .001", .002", .003", ..., .024" on the thimble.

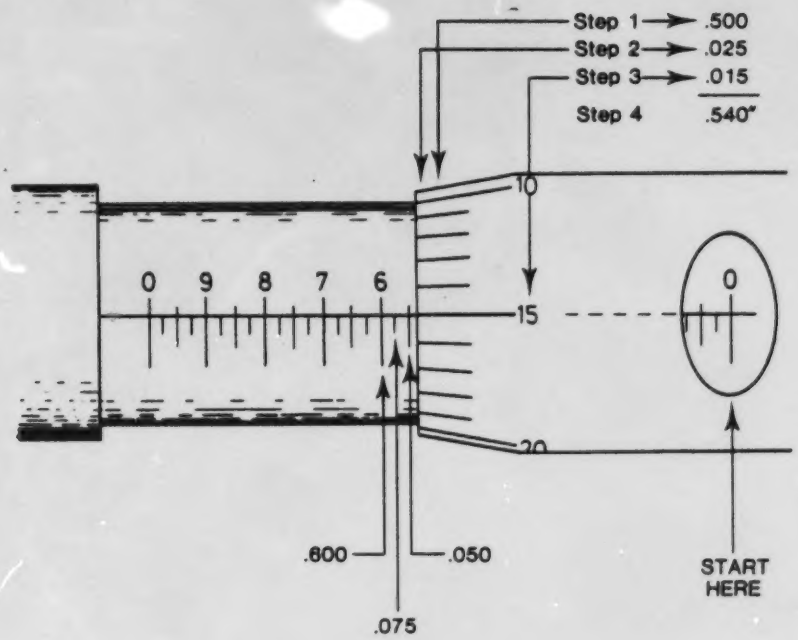


The machinist reads lines on the sleeve that he/she cannot see.
These lines are under the thimble.
He/she uses the lines on the sleeve that he/she can see to read the lines on the sleeve that he/she cannot see.
In this example, he/she can see the .700" line on the sleeve.
He/she knows that the .600" line is under the thimble.
He/she can also see the .050" line on the sleeve.
He/she knows that the .025" line is under the thimble.



He/she reads the line on the thimble.
Then, he/she adds the readings.

EXAMPLE H



The machinist always starts at 0.000"

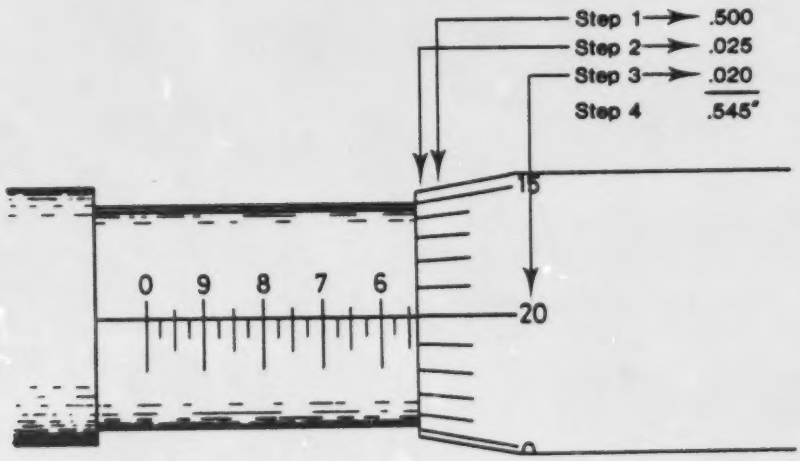
STEP 1. Read the .100", .200", .300", ..., .900" line on the sleeve.

STEP 2. Read the .025", .050", or .075" line on the sleeve.

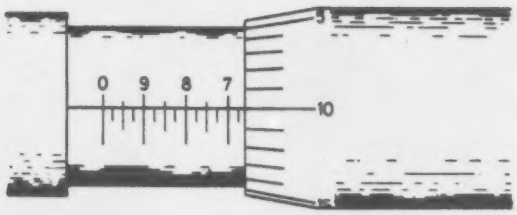
STEP 3. Read the .001", .002", .003", ..., .024" line on the thimble.

STEP 4. Add the readings from STEP 1, STEP 2, and STEP 3.
This is the dimension of the part.

EXAMPLE I

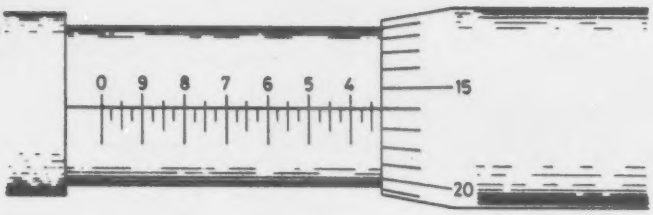


EXAMPLE J



STEP 1
STEP 2
STEP 3 _____
STEP 4

EXAMPLE K

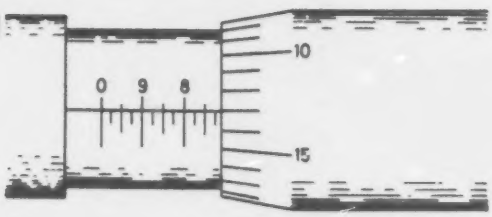


STEP 1
STEP 2
STEP 3 _____
STEP 4

EXAMPLE L

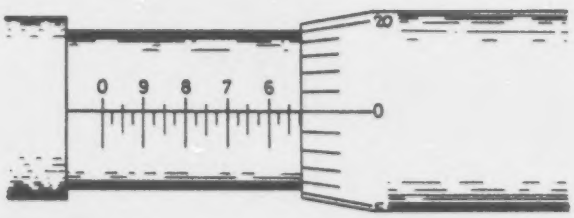
STEP 1
STEP 2
STEP 3 _____
STEP 4

EXAMPLE M



STEP 1
STEP 2
STEP 3 _____
STEP 4

EXAMPLE N



STEP 1
STEP 2
STEP 3 _____
STEP 4

Look on page 15 for the correct readings.

EXAMPLE J

.600
.050
.010
.660"

EXAMPLE K

.300
.025
.016
.341"

EXAMPLE L

.100
.075
.008
.183"

EXAMPLE M

.700
.000
.013
.713"

EXAMPLE N

.500
.025
.000
.525"

CARE OF MEASUREMENT TOOLS

These rules will help you make accurate measurements and accurate parts without damage to measurement tools.

Employers will want you to use measurement tools carefully and correctly.

GENERAL RULES

1. Do not drop measurement tools.
2. Do not carry measurement tools with other tools. You will drop or scratch the measurement tools.
3. Do not put measurement tools in a pile of tools.
4. Do not try to measure moving parts.
5. Do not remove rust or stains with abrasive cloth.
6. Wipe off measurement tools and then put the measurement tools away.

CARE OF MICROMETERS

1. Do not force the spindle against the part.
2. Do not use air hoses to clean a micrometer.
3. Do not put a micrometer on a machine tool. Chips and dirt will get in the micrometer.

Machine Shop Fundamentals

4D

UNIT 4: Measurement

LESSON 4D: Precision Measurement with Vernier Calipers and Vernier Height Gages.

OBJECTIVES:

1. The student will write the correct definition of precision measurement.
2. The student will match the names of the parts of a vernier caliper to the picture of a vernier caliper.
3. The student will write the steps to read a vernier caliper.
4. The student will write the correct vernier caliper reading from a picture of a vernier caliper reading.
5. The student will write the 3 ways a machinist can use a vernier height gage.
6. The student will choose the correct rules for the care of a vernier caliper and a vernier height gage.

PROCEDURES:

1. Read the Objectives.
2. Read the Lesson.
3. Watch the Slide Show.
4. Watch the teacher's Demonstration.
5. Do the Study Questions.
6. Do the Worksheets.
7. Do the Review Questions.
8. Do the Self-Test.

REFERENCES:

INTRODUCTION

For precision accuracy, the machinist uses precision measurement and precision measurement tools.

What is precision measurement?

PRECISION MEASUREMENT is the measurement of parts to within .001 of an inch or smaller.

The machinist uses precision measurement tools to measure thousandths (.001, .002, .003, ...,) of an inch and ten-thousandths (.0001, .0002, .0003, ...) of an inch.

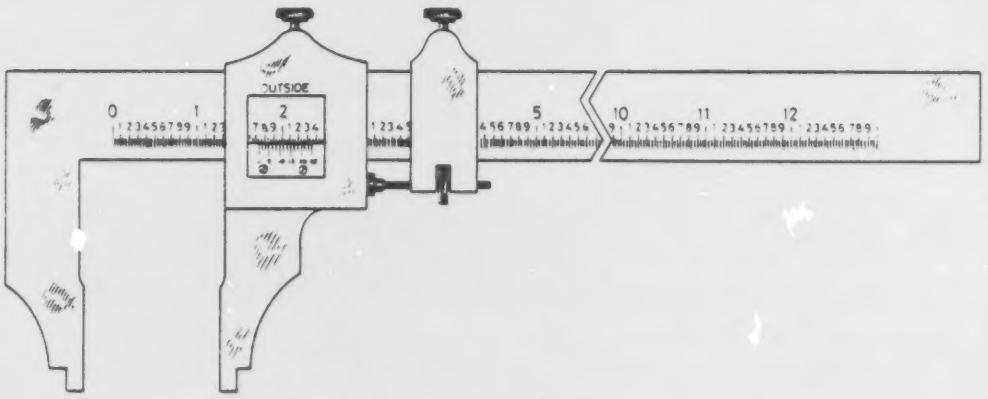
VERNIER CALIPERS

The machinist uses precision measurement tools to make precision measurements. He/she measures parts with precision measurement tools.
In this unit, you will learn to measure parts with these precision measurement tools:

1. The vernier caliper
2. The vernier height gage

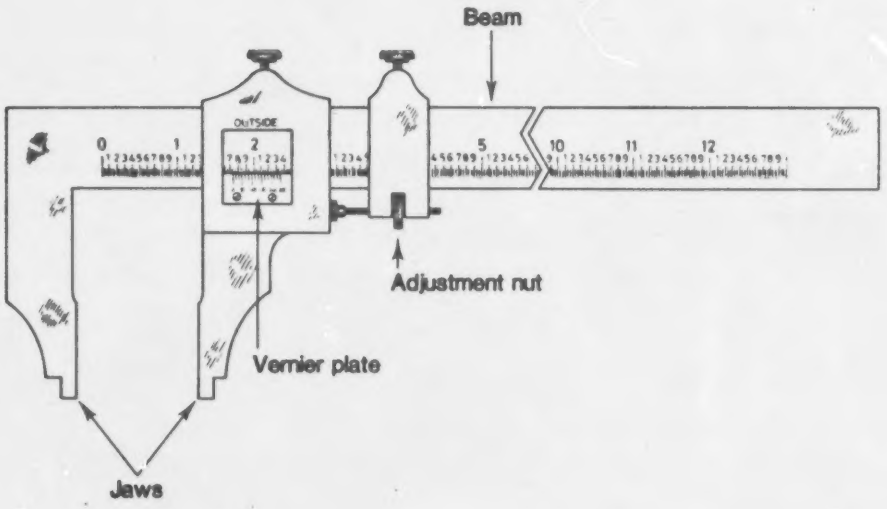
There are different kinds and sizes of vernier calipers and vernier height gages.

1. THE VERNIER CALIPER



The machinist uses the vernier caliper to measure outside dimensions and inside dimensions of parts.
He/she reads the measurements on the vernier caliper.
The machinist uses this vernier caliper to measure dimensions of parts from 0.000" to 13.000"

PARTS OF THE VERNIER CALIPER



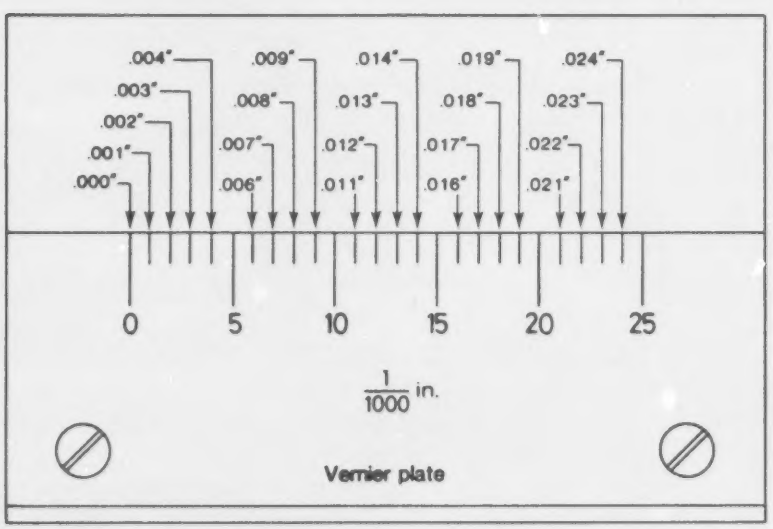
The machinist measures the outside dimensions and inside dimensions of parts with the JAWS of the vernier caliper.
He/she adjusts the jaws of the vernier caliper with the ADJUSTMENT NUT.
He/she reads 3 measurements on the BEAM.

a. He/she reads 1.000", 2.000", 3.000", ... on the beam.
b. He/she reads .100" to .900" on the beam.
c. He/she reads .025", .050", or .075" on the beam.

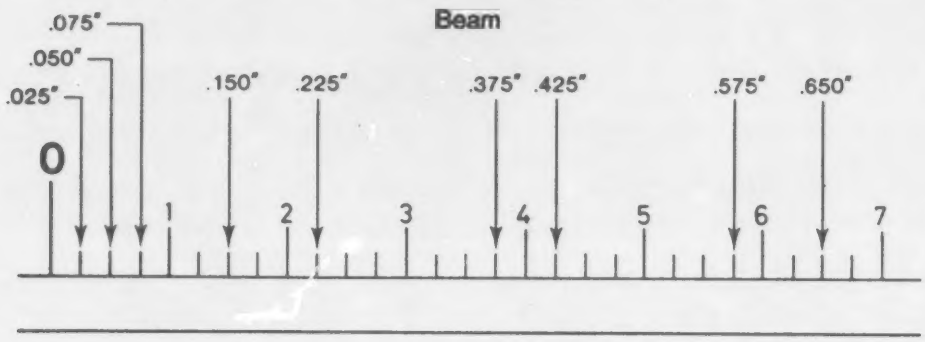
He/she reads 1 measurement on the VERNIER PLATE.

d. He/she reads .001" to .024" on the vernier plate.

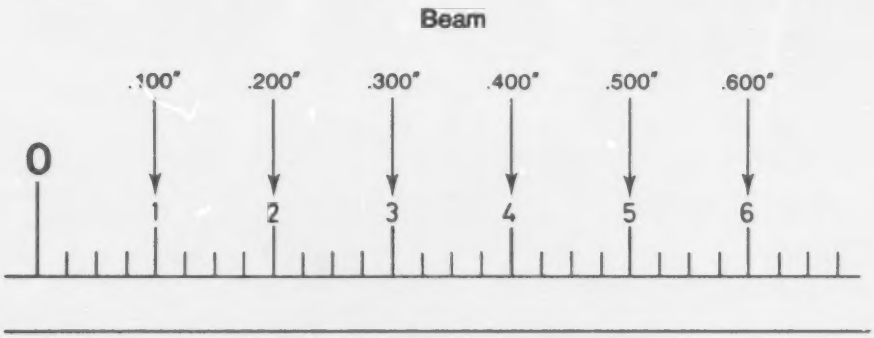
READING THE VERNIER CALIPER



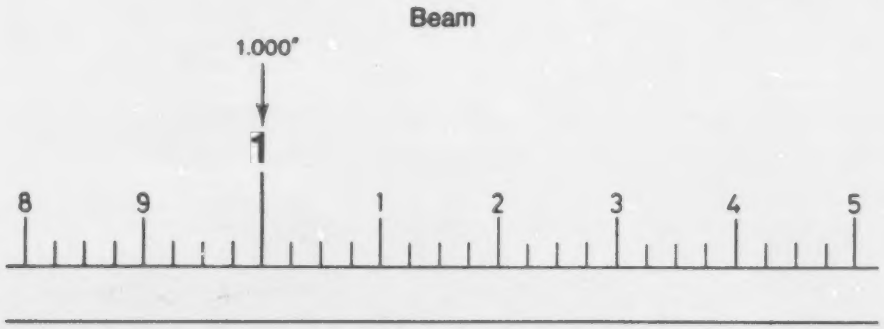
The machinist reads each line on the vernier plate as .001"
He/she reads .001" to .024" on the vernier plate.



The machinist reads each line without a number on the beam as .025"
He/she reads .025", .050", and .075" on the beam.



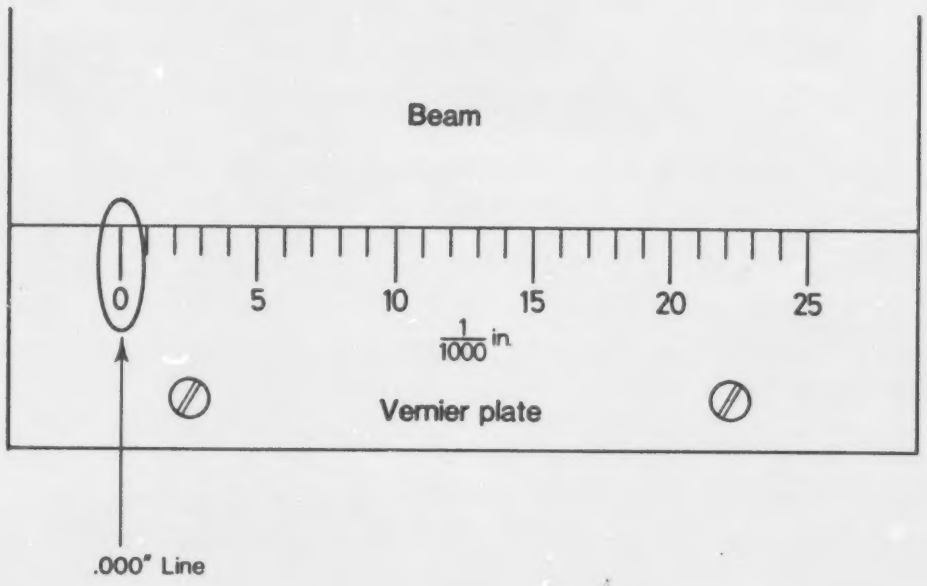
The machinist reads each line with a small number (1 to 9) on the beam as .100"
He/she reads .100" to .900" on the beam.

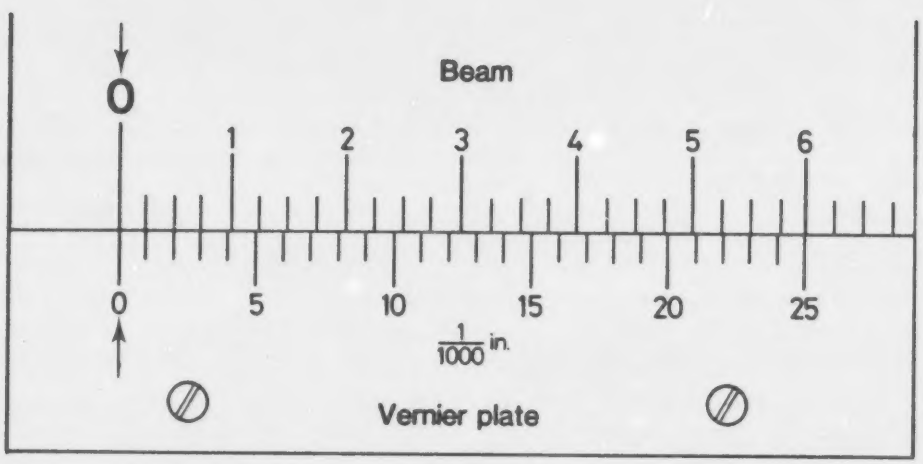


The machinist reads each line with a large number on the beam as 1.000"
He/she reads inches (1.000", 2.000", 3.000", ...) on the beam.

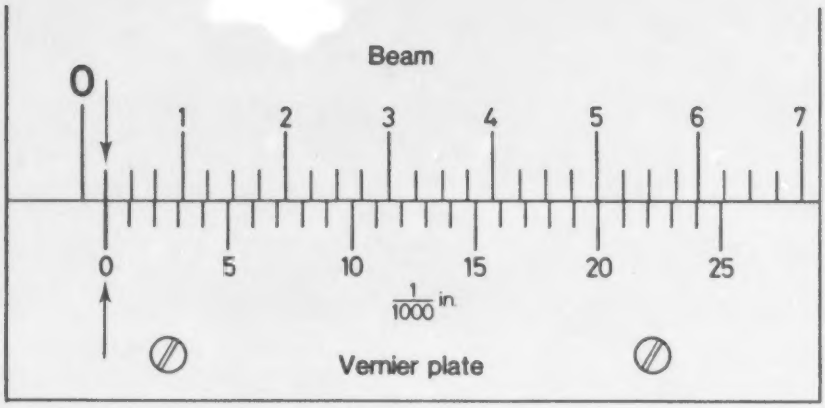
The machinist looks at the .000" line on the vernier plate to read:

- the inches line (1.000", 2.000", 3.000", ...) on the beam.
- the .100", .200", .300", ..., .900" line on the beam.
- the .025", .050", or .075" line on the beam.

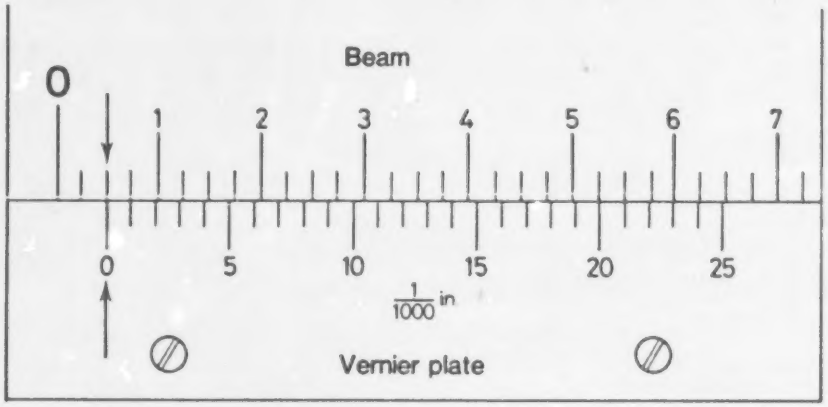




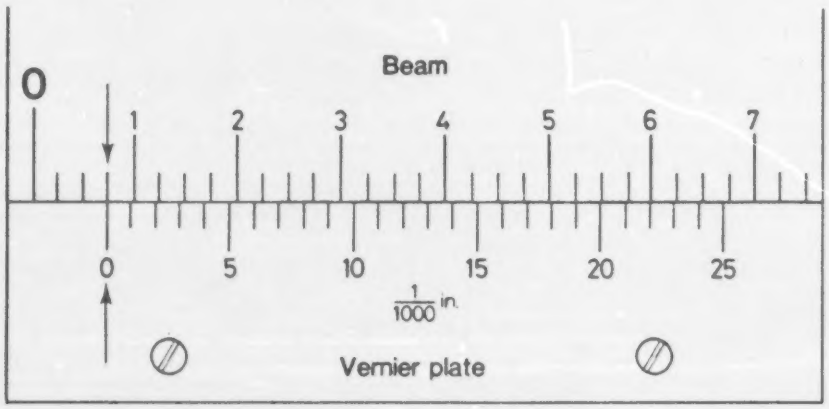
This vernier caliper reading is 0.000"
The .000" line on the vernier plate lines up with the 0.000" line on the beam.



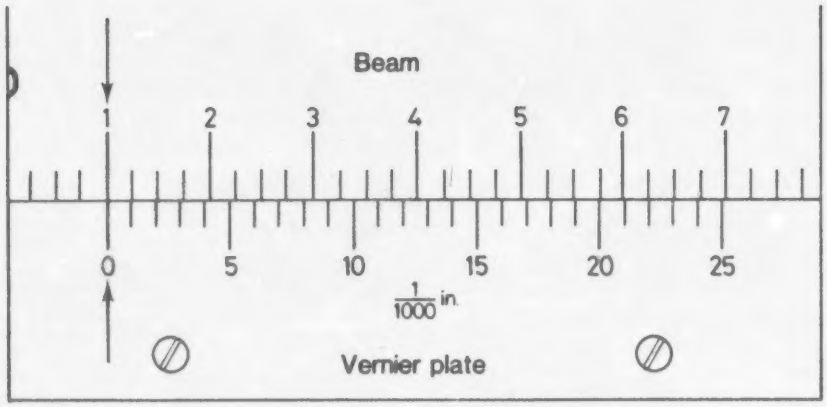
This vernier caliper reading is .025"
The .000" line on the vernier plate lines up with the .025" line on the beam.



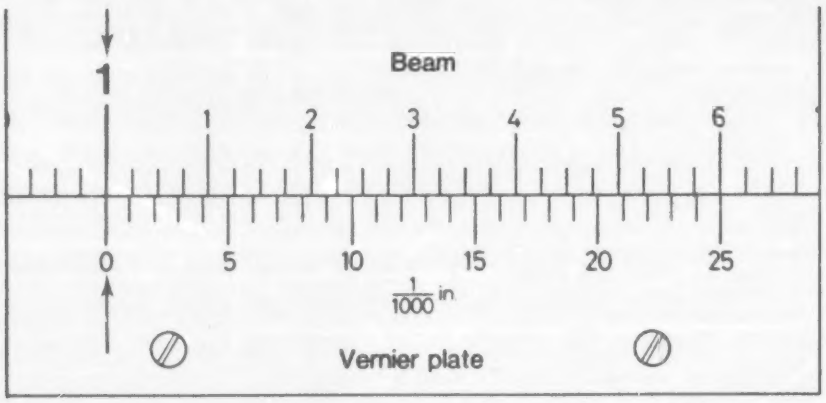
This vernier caliper reading is .050"
The .000" line on the vernier plate lines up with the .050" on the beam.



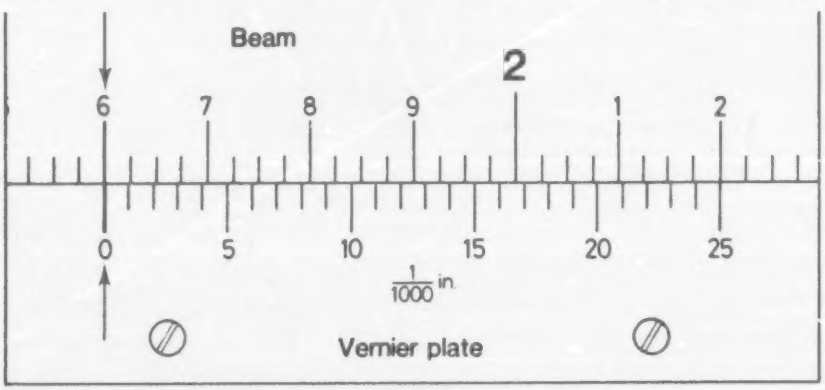
This vernier caliper reading is .075"
The .000" line on the vernier plate lines up with the .075" on the beam.



This vernier caliper reading is .100"
The .000" line on the vernier plate lines up with the .100" line on the beam.

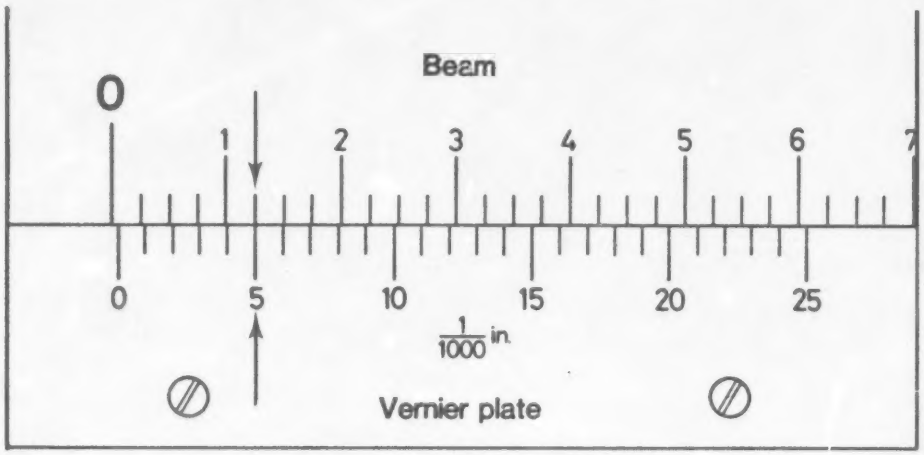


This vernier caliper is 1.000"
The .000" line on the vernier plate lines up with the 1.000" line on the beam.

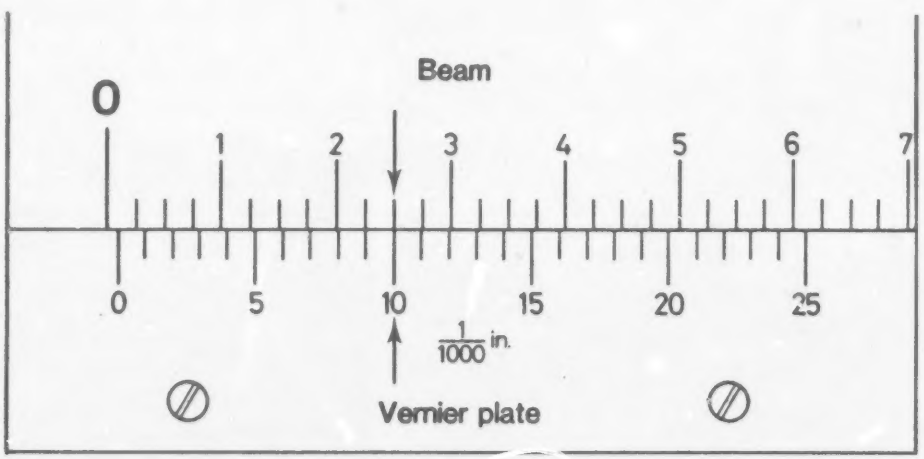


This vernier caliper reading is 1.600"
The machinist knows the reading is 1.000" + .600" = 1.600"
The machinist cannot see the 1.000" line, but he/she can see the 2.000" line.
The .000" line on the vernier plate lines up with the .600" line on the beam.

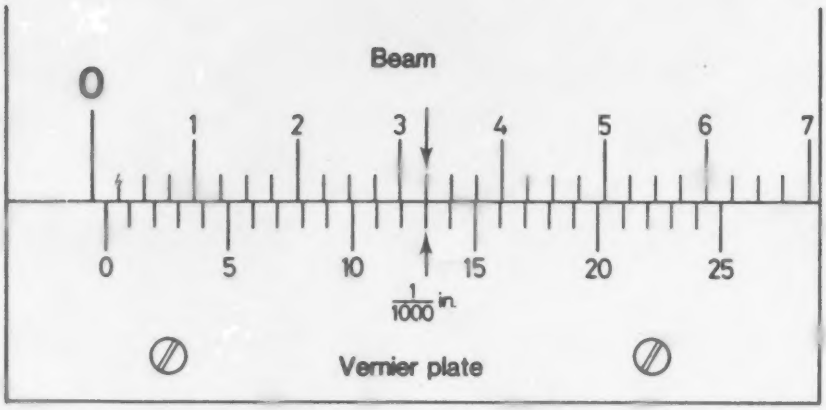
Sometimes the .000" line on the vernier plate does not line up with a line on the beam.
Then, the machinist must read thousandths of an inch (.001", .002", .003", ..., .024")
He/she reads thousandths of an inch (.001", .002", .003, ..., .024") on the vernier plate.
The vernier plate is like the thimble on a micrometer.



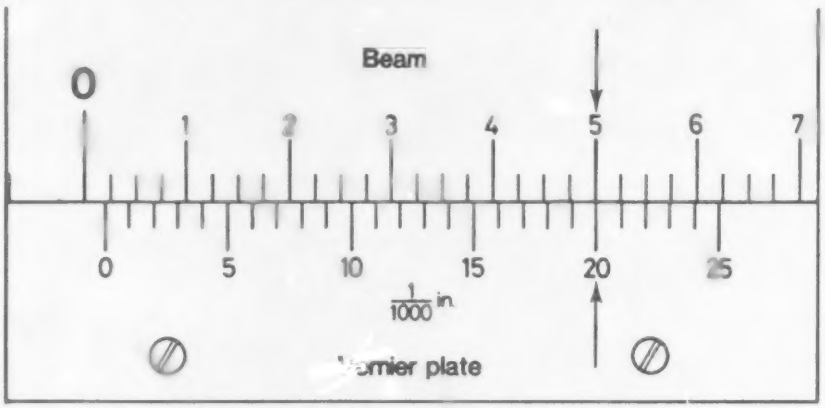
In this reading, the .000" line on the vernier plate does not line up with a line on the beam.
The machinist must read the thousandths of an inch on the vernier plate.
To read the thousandths of an inch (.001", .002", ..., .024"), the machinist carefully looks for a line on the vernier plate that lines up with a line on the beam.
He/she reads the thousandths line on the vernier plate.
He/she reads .005" in this reading.
This vernier caliper reading is .005"



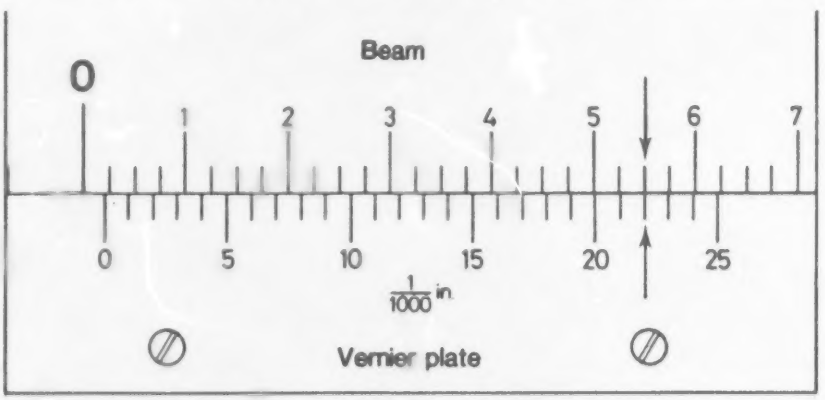
This vernier caliper reading is .010"
The .010" line on the vernier plate lines up with a line on the beam.



This vernier caliper reading is .013"
The .013" line on the vernier plate lines up with a line on the beam.



This vernier caliper reading is .020"
The .020" line on the vernier plate lines up with a line on the beam.



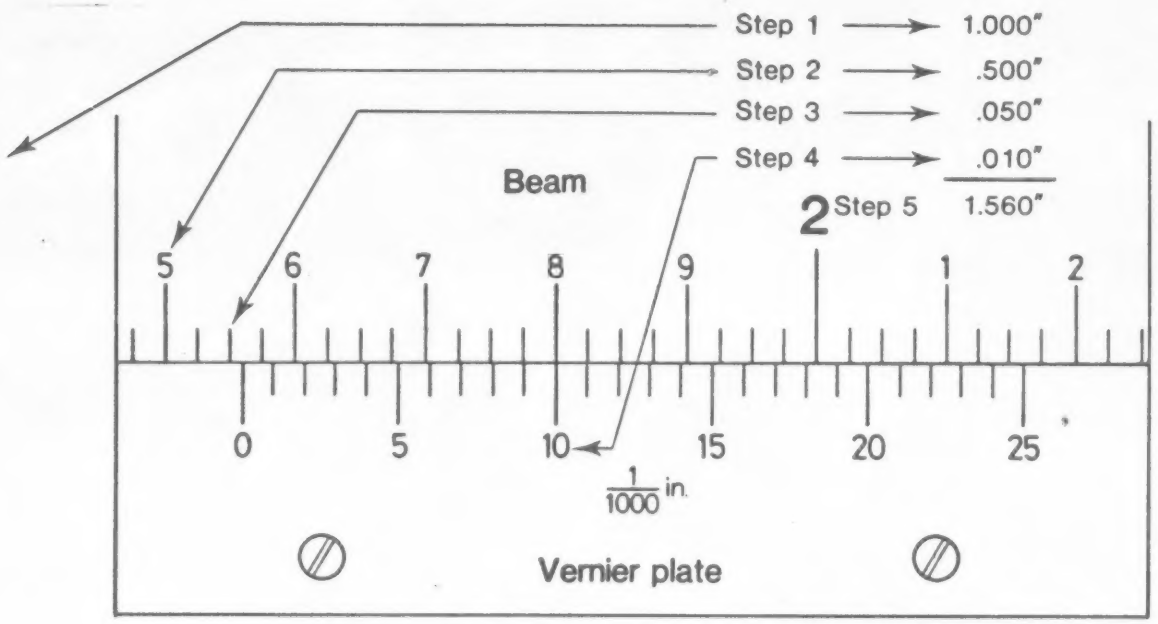
This vernier caliper reading is .022"
The .022" line on the vernier plate lines up with a line on the beam.

The machinist always starts at 0.000" or the left side of the beam.
He/she reads the vernier caliper from left to right.

The machinist reads:

- the 1.000", 2.000", 3.000", ..., line on the beam.
- the .100", .200", .300", ..., .900" line on the beam.
- the .025", .050", or .075" line on the beam.
- the .001", .002", .003", ..., .024" line on the vernier plate.

EXAMPLE A



STEP 1. Read the 1.000", 2.000", 3.000", ..., line on the beam.

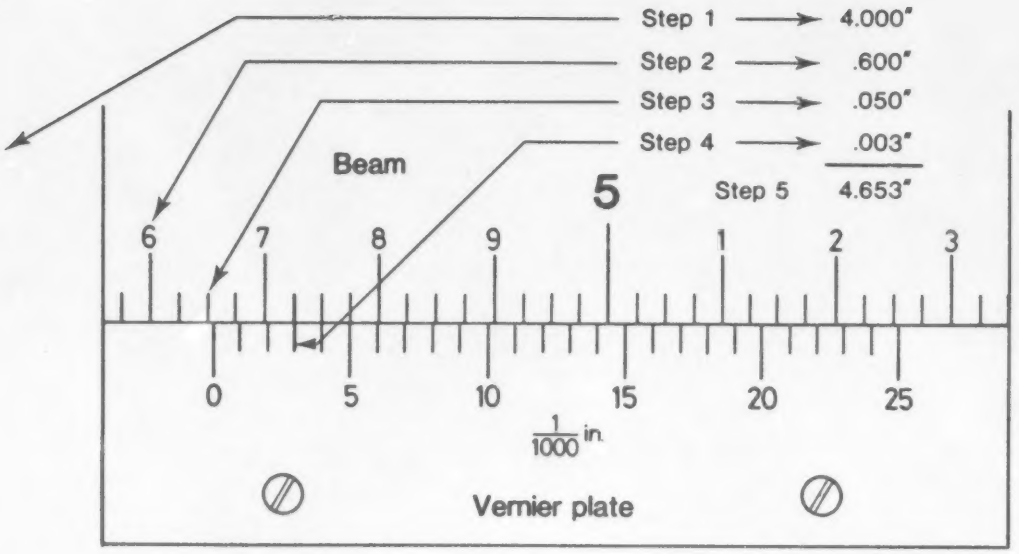
STEP 2. Read the .100", .200", .300", ..., .900" line on the beam.

STEP 3. Read the .025", .050", or .075" line on the beam.

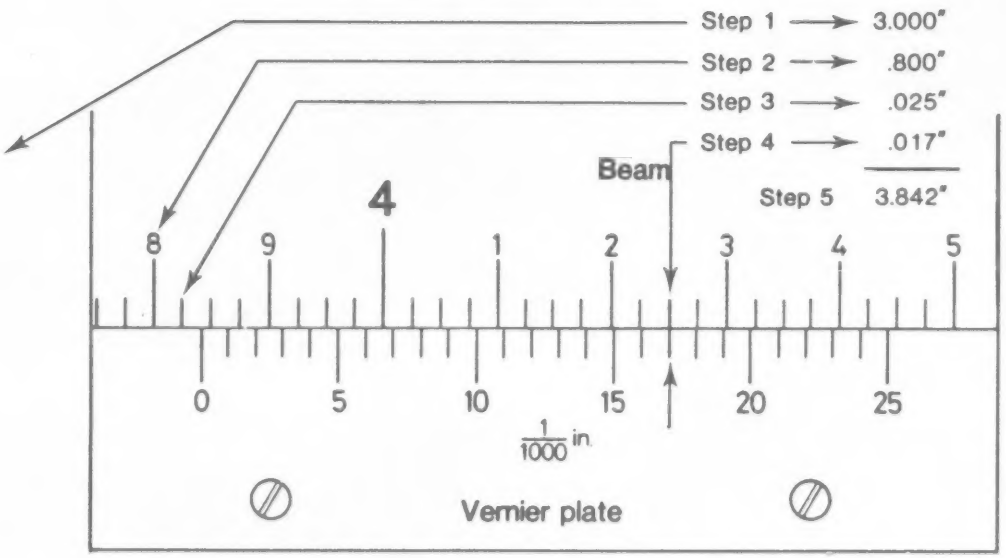
STEP 4. Read the .001", .002", .003", ..., .024" line on the vernier plate that lines up exactly with a line on the beam.

STEP 5. Add the reading from STEP 1, STEP 2, STEP 3, and STEP 4. This is the measurement of the part.

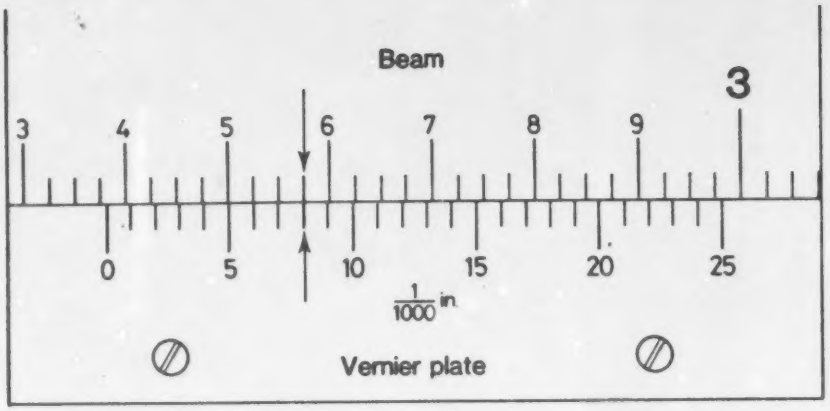
EXAMPLE B



EXAMPLE C



EXAMPLE D



STEP 1.

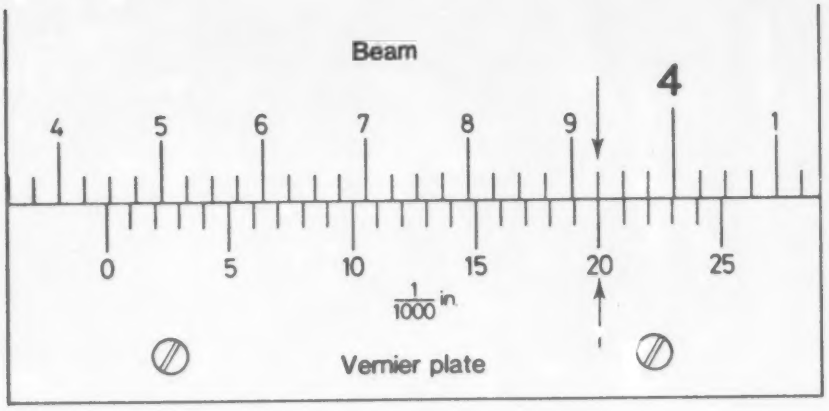
STEP 2.

STEP 3.

STEP 4. _____

STEP 5.

EXAMPLE E



STEP 1.

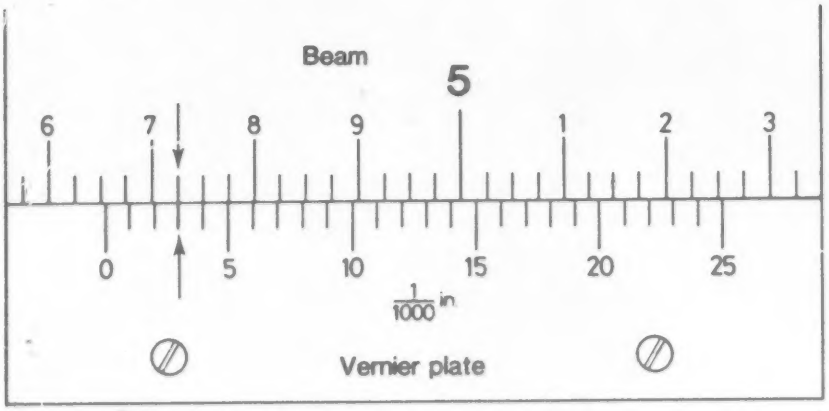
STEP 2.

STEP 3.

STEP 4. _____

STEP 5.

EXAMPLE F



STEP 1.

STEP 2.

STEP 3.

STEP 4. _____

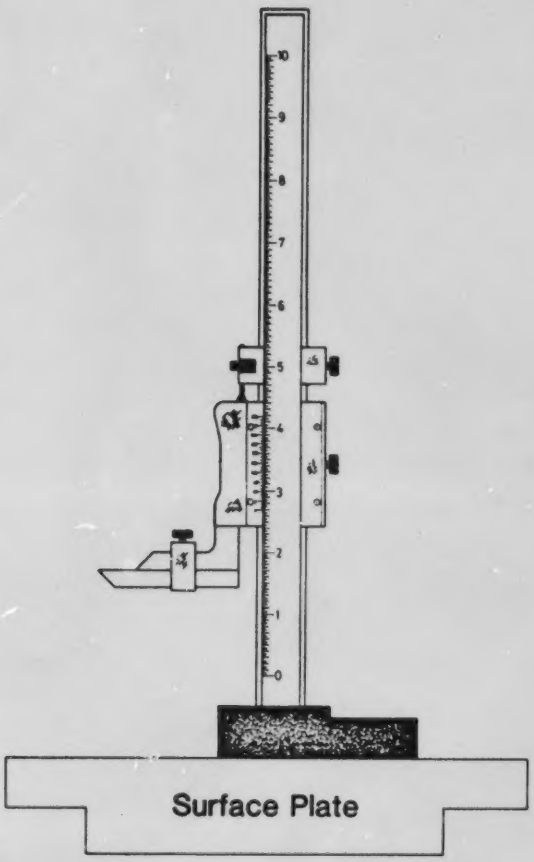
STEP 5.

EXAMPLE D reading is 2.383"

EXAMPLE E reading is 3.445"

EXAMPLE F reading is 4.653"

2. THE VERNIER HEIGHT GAGE



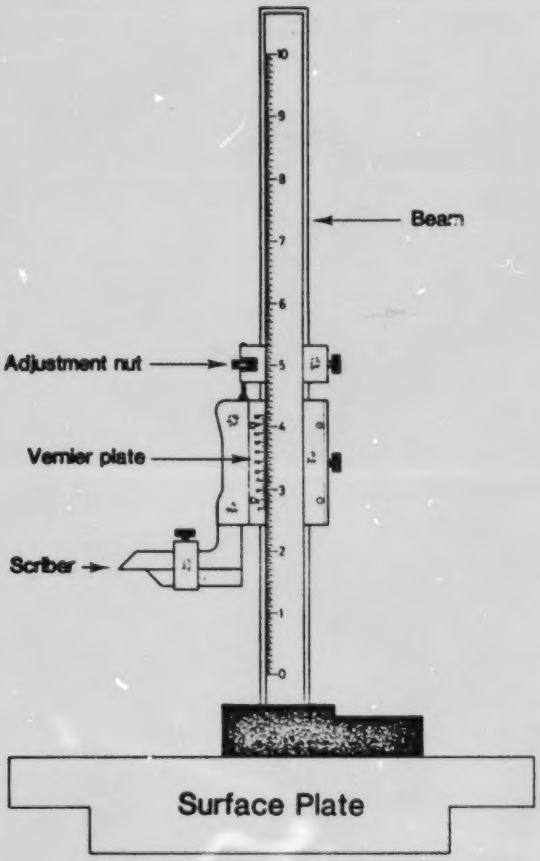
The machinist uses the vernier height gage to measure outside dimensions of parts.
He/she can measure the height, length, and width of parts.

He/she also uses the vernier height gage to lay out dimensions on parts.
First, he/she adjusts the vernier height gage to the correct dimension.
Then, he/she marks the correct dimension on the part with the vernier height gage.
Marking the correct dimensions on parts is called LAYOUT.
You will learn more about LAYOUT in a later unit.

The machinist must use a very flat and smooth surface to measure parts and lay out parts with the vernier height gage.
He/she uses a SURFACE PLATE.
A surface plate is very flat and smooth.

The machinist puts the vernier height gage and the part on the surface plate.
He/she must carefully clean the surface plate, the bottom of the vernier height gage, and the part to make accurate measurements.
Dirt or metal chips on the surface plate, the bottom of the vernier height gage, or the part make inaccurate measurements.

PARTS OF THE VERNIER HEIGHT GAGE



The machinist measures dimensions on parts between the SCRIBER and the surface plate.
He/she lays out correct dimensions on parts with the SCRIBER.
He/she adjusts the scriber of the vernier height gage with the ADJUSTMENT NUT.
He/she reads 3 measurements on the BEAM.

a. He/she reads 1.000", 2.000", 3.000", ...
b. He/she reads .100" to .900" on the beam.
c. He/she reads .025", .050", or .075" on the beam.

He/she reads 1 measurement on the VERNIER PLATE.

d. He/she reads .001" to .024" on the vernier plate.

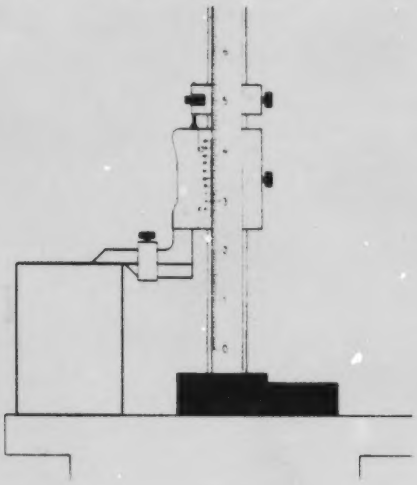
The machinist can use the vernier height gage in 3 ways:

1. To measure over a surface on a part.

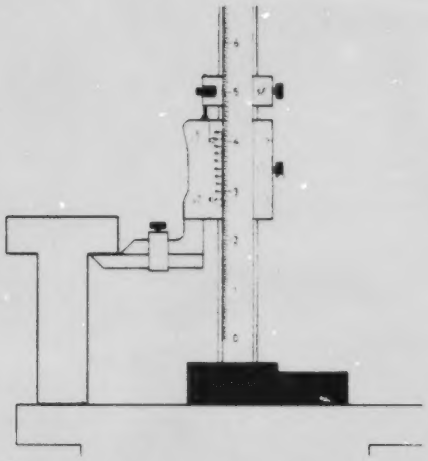
2. To measure under a surface on a part.

3. To lay out a correct dimension on a part.

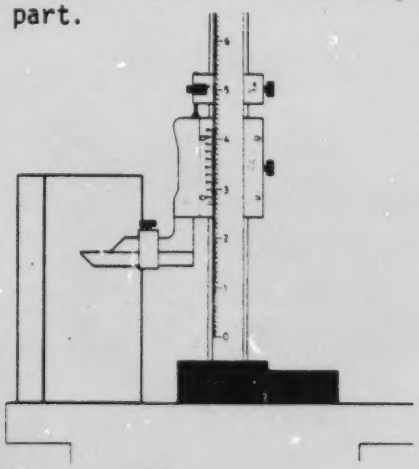
1. MEASURING OVER A SURFACE
The machinist sets the scriber on the vernier height gage to measure over a surface on a part.



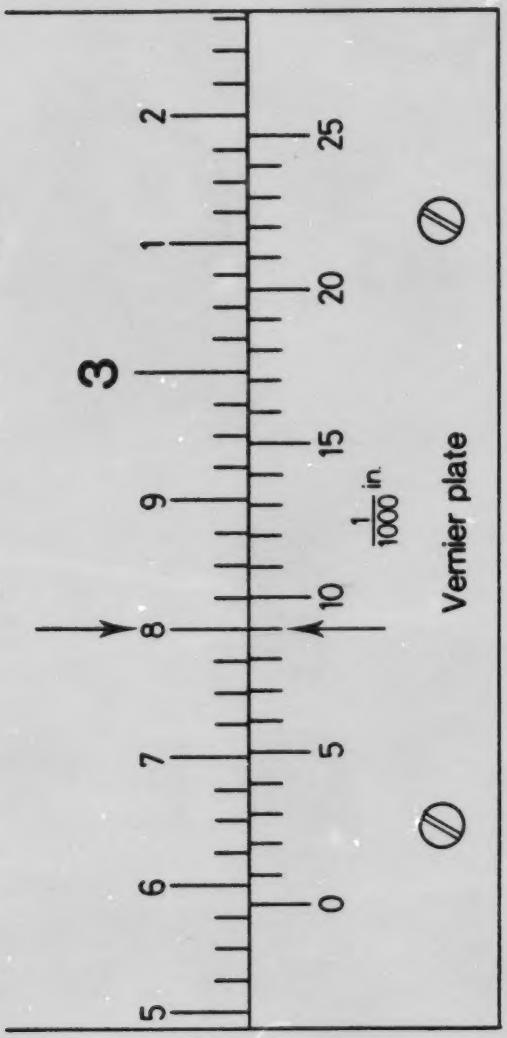
2. MEASURING UNDER A SURFACE
The machinist sets the scriber on the vernier height gage to measure under a surface on a part.



3. LAYING OUT A CORRECT DIMENSION
The machinist sets the scriber on the vernier height gage to lay out a correct dimension on a part.



READING THE VERNIER HEIGHT GAGE



STEP 1.	2.000"
STEP 2.	.500"
STEP 3.	.075"
STEP 4.	.009"
STEP 5.	2.584"

The machinist reads thousandths of an inch (.001") on the vernier height gage.
He/she reads the vernier height gage the same way he/she reads the vernier caliper.

He/she reads 1.000", 2.000", 3.000", ... on the beam.
He/she reads .100" to .900" on the beam.
He/she reads .025", .050", or .075" on the beam.
He/she reads .001" to .024" on the vernier plate.

CARE OF MEASUREMENT TOOLS

These rules will help you make accurate measurements and accurate parts without damage to measurement tools.

Employers will want you to use measurement tools carefully and correctly.

GENERAL RULES

1. Do not drop measurement tools.
2. Do not carry measurement tools with other tools.
   You will drop or scratch the measurement tools.
3. Do not put measurement tools in a pile of tools.
4. Do not try to measure moving parts.
5. Do not remove rust or stains with abrasive cloth.
6. Wipe off measurement tools and then put the measurement tools away.

CARE OF VERNIER CALIPERS AND VERNIER HEIGHT GAGES

1. Wipe off the vernier caliper and the vernier height gage before you use them and after you use them.
2. Once in a while, put light machine oil on the sliding surfaces on the beam of the vernier caliper and the vernier height gage.
3. Do not force the jaws of the vernier caliper or the scriber of the vernier height gage against a part.
4. Do not use an air hose to clean a vernier caliper or a vernier height gage.
5. Do not put a vernier caliper or a vernier height gage on top of a machine tool.
   Metal chips and dirt will get in the vernier caliper and vernier height gage.

Machine Shop Fundamentals

4E

UNIT 4: Measurement

LESSON 4E: Precision Measurement with Dial Indicators

OBJECTIVES:

1. The student will write the correct definition of precision measurement.
2. The student will write 2 ways the machinist uses a dial indicator.
3. The student will match the names of the parts of a dial indicator to a picture of a dial indicator.
4. The student will write the correct dial indicator reading from a picture of a dial indicator reading.
5. The student will write the 2 definitions of alignment.
6. The student will choose the correct rules for the care of dial indicators.

PROCEDURES:

1. Read the Objectives.
2. Read the Lesson.
3. Watch the Slide Show.
4. Watch the teacher's Demonstration.
5. Do the Study Questions.
6. Do the Worksheets.
7. Do the Review Questions.
8. Do the Self-Test.

REFERENCES:

INTRODUCTION

PRECISION MEASUREMENT is the measurement of parts to within .001 of an inch or smaller.

The machinist uses precision measurement tools to measure thousandths (.001, .002, .003, ...) of an inch and ten-thousandths (.0001, .0002, .0003, ...) of an inch.

DIAL INDICATORS

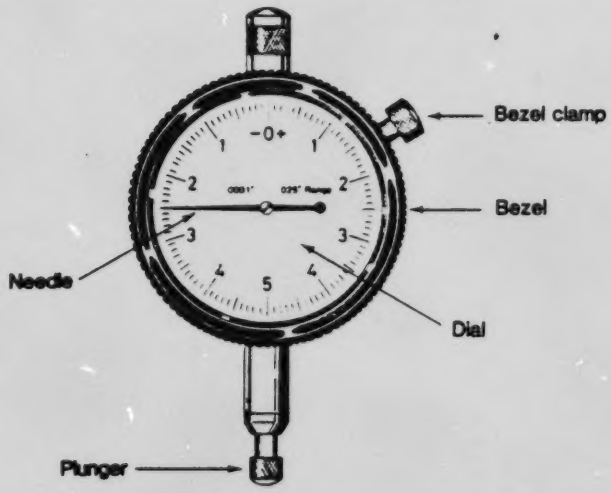
Dial indicators are precision measurement tools.
Some dial indicators measure thousandths (.001) of an inch.
Other dial indicators measure ten-thousandths (.0001) of an inch.

The machinist uses dial indicators in 2 ways:

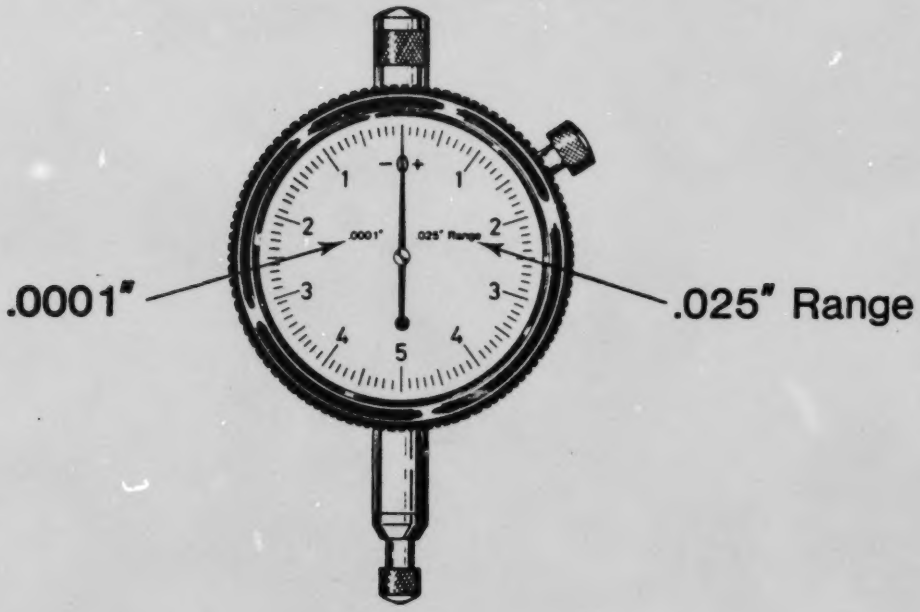
1. To check parts
2. To set up machine tools

There are many different kinds and sizes of dial indicators.

PARTS OF THE DIAL INDICATOR



The PLUNGER moves in and out of the dial indicator.
The plunger moves the NEEDLE.
The DIAL has lines, large numbers, and small numbers.
The BEZEL holds the dial.
The machinist turns the bezel to line up the zero (0) on the dial and the needle.
The BEZEL CLAMP holds the bezel.
The machinist loosens the bezel clamp to turn the bezel and dial.
Then, he/she tightens the bezel clamp.



One of the small numbers on the dial tells the machinist how much each line on the dial is in thousandths (.001) of an inch or in ten-thousandths (.0001) of an inch.
On this dial indicator, each line is .0001"

The other small number on the dial tells the machinist the RANGE of the dial indicator.
The range is the maximum distance the plunger can move into the dial indicator.
On this dial indicator, the range is .025"

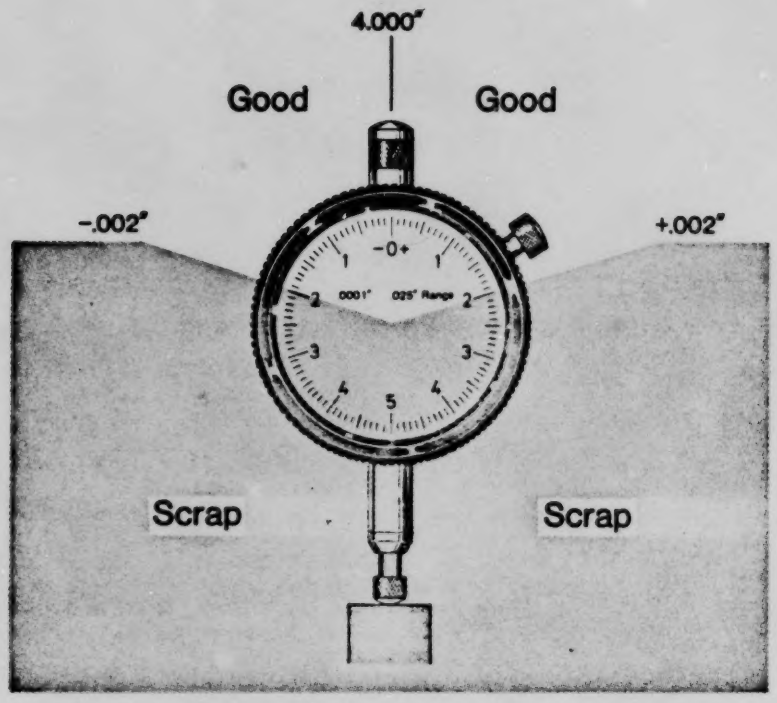
CHECKING PARTS WITH DIAL INDICATORS

The machinist uses dial indicators to check the dimensions of parts.
The machinist can quickly check many of the same kind of parts with a dial indicator.

Machinists are not perfect.
Machine tools are not perfect.
A machinist cannot always make perfect dimensions on every part.

Each dimension of a part can be a little larger or a little smaller than the perfect dimension and still be good.
The blueprint gives the perfect dimensions of a part.
The blueprint also gives the tolerance of each perfect dimension.
The tolerance of a perfect dimension is how much larger or how much smaller the dimension can be and still be good.
TOLERANCE is the amount of acceptable size variation of a dimension.
(See Lesson 5D for more information about tolerances.)

For example:

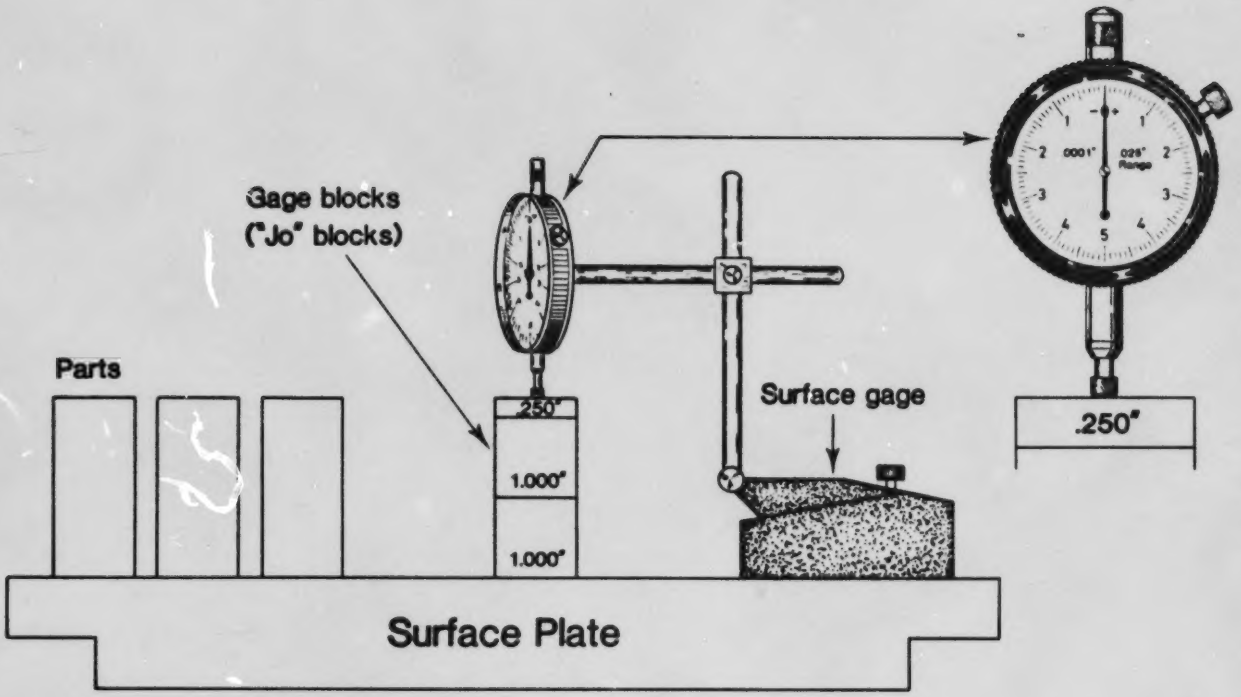


The perfect dimension is 4.000"
The tolerance is ± .002"
The dimension can be .002" larger or .002" smaller than the perfect dimension and still be good.
In other words, the dimension can be between 4.002" and 3.998", and still be good.

A dial indicator measures the amount of size variation from the perfect dimension.
With a dial indicator, the machinist checks to see if the dimension of a part is in tolerance (good) or out of tolerance (scrap).

Some dial indicators measure thousandths (.001, .002, .003, ...) of an inch.
Other dial indicators measure ten-thousandths (.0001, .0002, .0003, ...) of an inch.

The machinist must use a very flat and smooth surface to check parts with the dial indicator.
He/she uses a SURFACE PLATE.
A surface plate is very flat and smooth.
The SURFACE GAGE holds the dial indicator.
The machinist must carefully clean the surface plate, the bottom of the surface gage, and the parts.



First, the machinist sets up a distance that he/she knows is exact.
He/she uses GAGE BLOCKS ("JO" BLOCKS) to set up an exact distance between the surface plate and the plunger.
Gage blocks are metal blocks for precision measurement.
Companies make gage blocks to very exact sizes.
There are many sizes of gage blocks.
The machinist chooses the gage blocks that he/she needs to set up an exact distance.

Next, the machinist puts the plunger of the dial indicator on the gage blocks.
He/she loosens the bezel clamp.
He/she turns the bezel to line up the needle and the zero (0) on the dial.
He/she tightens the bezel clamp.
Now, he/she knows the distance between the surface plate and the plunger is an exact distance.

Next, he/she moves the dial indicator and the surface gage.

Last, he/she puts the plunger on a part.
He/she reads the dial of the dial indicator.
If the needle is on zero (0), the dimension of the part is the perfect dimension.
If the needle is not on the zero (0), the dimension is larger or smaller than the perfect dimension.
The dial indicator shows the amount of size variation from the perfect dimension.
The machinist checks to see if the dimension of the part is in tolerance or out of tolerance.

READING THE DIAL INDICATOR

First, the machinist sets up an exact distance with gage blocks.
Now he/she knows the exact distance between the surface plate and plunger.
Then, he/she checks the parts.
He/she reads the dial to check the amount of size variation from the perfect dimension.

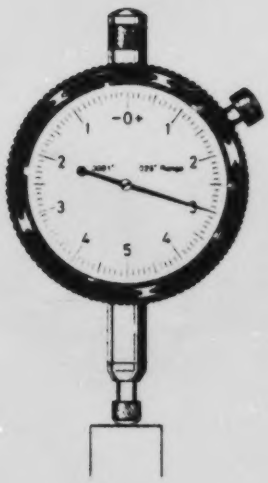
Here a machinist already set up a 4.000" distance with gage blocks.
The perfect dimension is 4.000" with a tolerance of ± .002"
On this dial indicator, each line is .0001"
On this dial indicator, the range is .025"
He/she already set a zero point.
Now, he/she will check parts.

This dial indicator reading is .000"
This dimension is the perfect dimension or 4.000"
This dimension is in tolerance (good).

This dial indicator reading is +.002
This dimension is .002" larger than the perfect dimension.
This dimension is in tolerance (good).

This dial indicator reading is -.001"
This dimension is .001" smaller than the perfect dimension.
This dimension is in tolerance (good).

This dial indicator reading is -.004"
This dimension is .004" smaller than the perfect dimension.
This dimension is out of tolerance (scrap).



This dial indicator reading is +.003"
This dimension is .003" larger than the perfect dimension.
This dimension is out of tolerance (scrap).

SETTING UP MACHINE TOOLS WITH DIAL INDICATORS

The machinist often uses the dial indicator to set up machine tools.
Many times, he/she must line up 2 parts (general meaning) of a machine tool to set up the machine tool.
He/she must line up the 2 parts of the machine tool to make accurate parts.

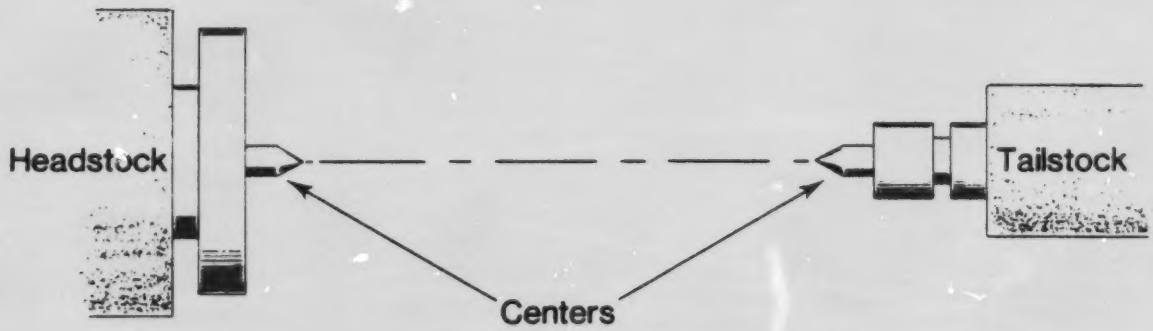
What is alignment?

Making 2 parts of a machine tool line up exactly straight is called ALIGNMENT.
Making 2 parts of a machine tool line up exactly parallel is called ALIGNMENT.

The machinist uses a dial indicator to align 2 parts of a machine tool.
The dial indicator shows any variation in the alignment of 2 parts of a machine tool.

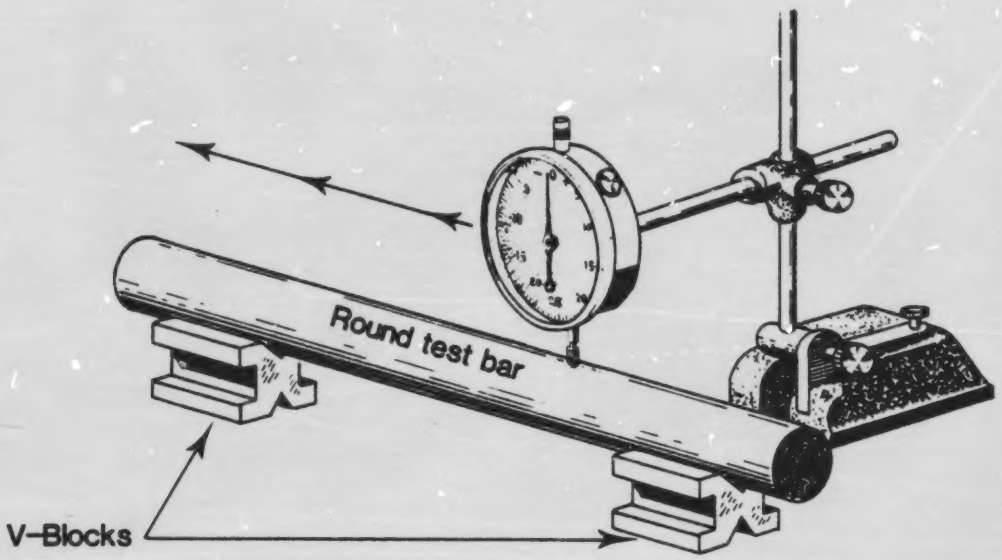
ALIGNING THE CENTERS OF THE LATHE

The machinist must align the centers of the lathe to make accurate parts.
One center is in the headstock of the lathe.
The other center is in the tailstock of the lathe.
The machinist sets up round parts between the centers of the lathe for many lathe operations.



The centers of the lathe must be exactly straight.
The machinist must align the center in the tailstock to the center in the headstock.
He/she uses a dial indicator and a round test bar to align the center in the tailstock to the center in the headstock.

The machinist must check the straightness of the round test bar with a dial indicator.
This round test bar has a tolerance of ± .0005"



First, the machinist sets up the round test bar between 2 V-BLOCKS on the surface plate.
Companies make V-blocks to very exact sizes.
The machinist uses V-blocks to do many things in the shop.

Next, the machinist puts the plunger of the dial indicator on one end of the round test bar.
He/she sets a zero point.
He/she turns the bezel to line up the needle and the zero (0) on the dial.

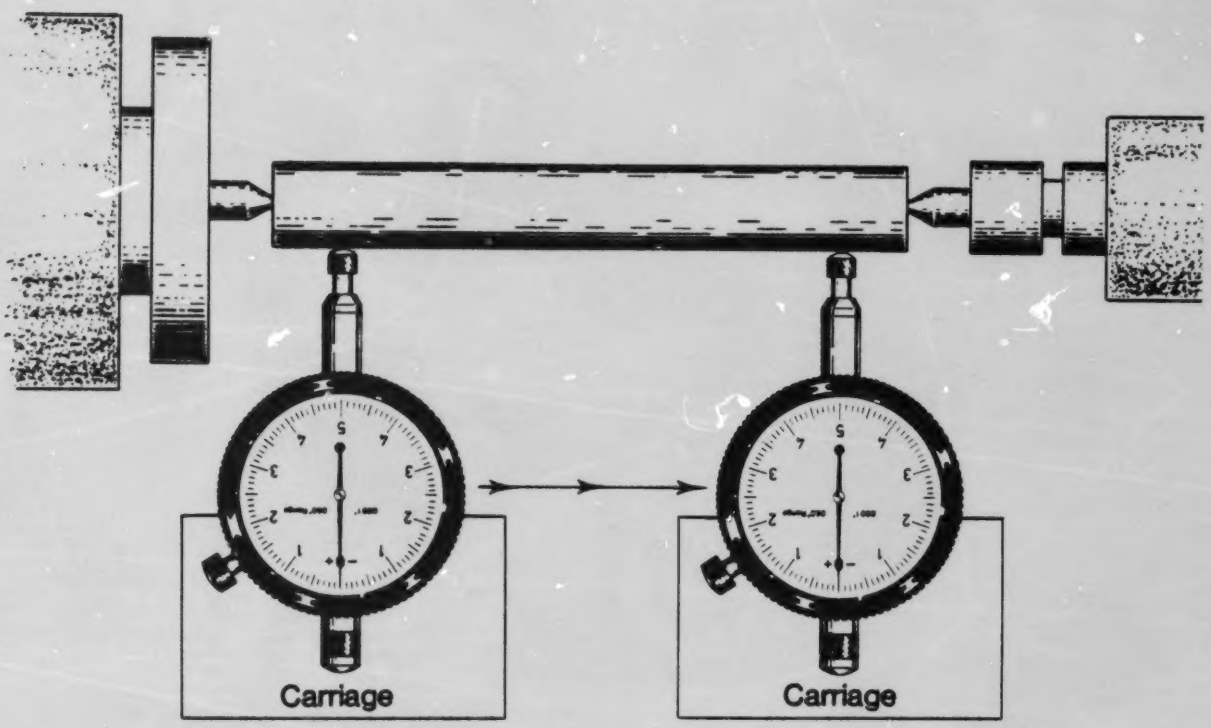
Then, he/she moves the plunger of the dial indicator along the round test bar.
He/she moves the plunger from one end of the round test bar to the other end of the round test bar.
The machinist reads the dial to check the straightness of the bar.

If the reading is more than +.0005" or more than -.0005", the round test bar is not in tolerance.
Then, the machinist must check another round test bar.

If the reading is less than +.0005" or less than -.0005", the round test bar is in tolerance.

Now, the machinist is ready to align the centers of the lathe.
Here, align means to make two parts of a machine tool straight.

First, the machinist sets up the round test bar between the centers of the lathe.



Next, he/she sets up the dial indicator on the carriage of the lathe.

Then, he/she puts the plunger of the dial indicator on one end of the bar.
He/she moves the carriage to move the plunger of the dial indicator.

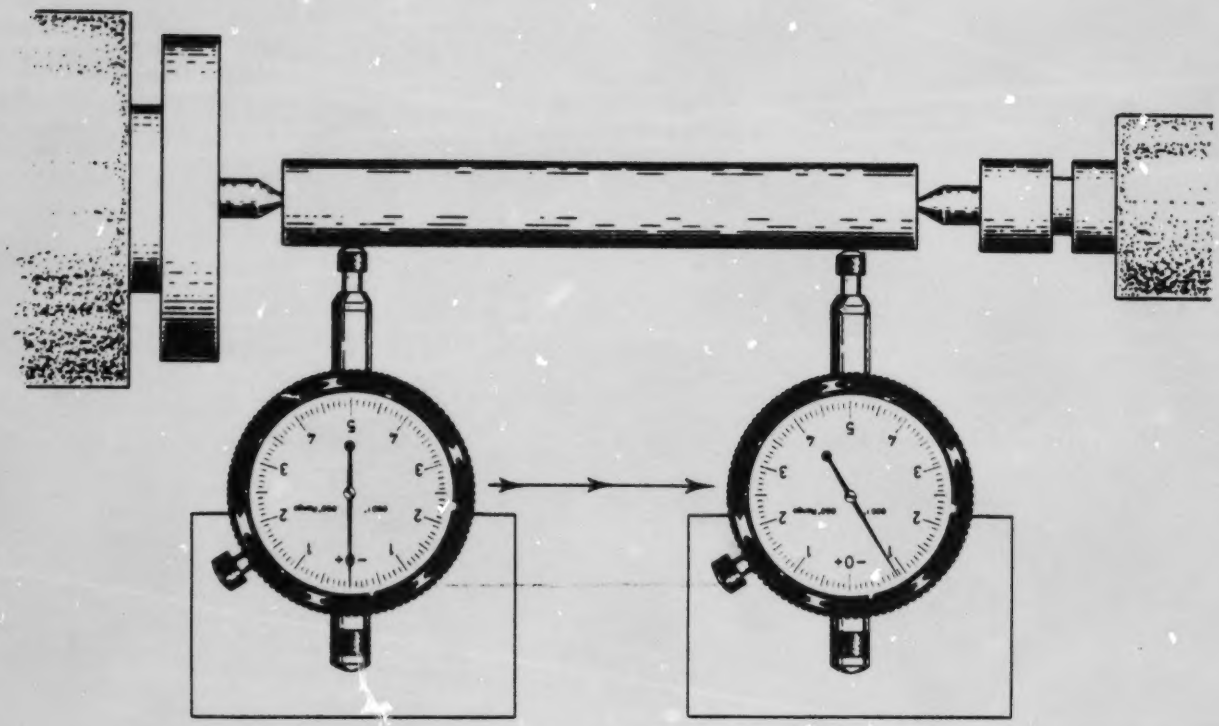
Next, he/she sets a zero point.
He/she turns the bezel to line up the needle and the zero (0) on the dial.

Then, he/she moves the plunger of the dial indicator along the round test bar.
He/she moves the plunger from one end of the round test bar to the other end of the round test bar.

Last, he/she reads the dial to check if the centers of the lathe are straight.

If the needle of the dial indicator does not move from the zero point, the machinist knows the centers of the lathe are straight.
Then he/she does not have to align the centers of the lathe.

If the needle of the dial indicator moves from the zero point, the machinist knows the centers of the lathe are not straight.



Then, he/she must align the center in the tailstock to the center in the headstock.
The machinist must adjust the tailstock to move the center in the tailstock.

He/she adjusts the tailstock.

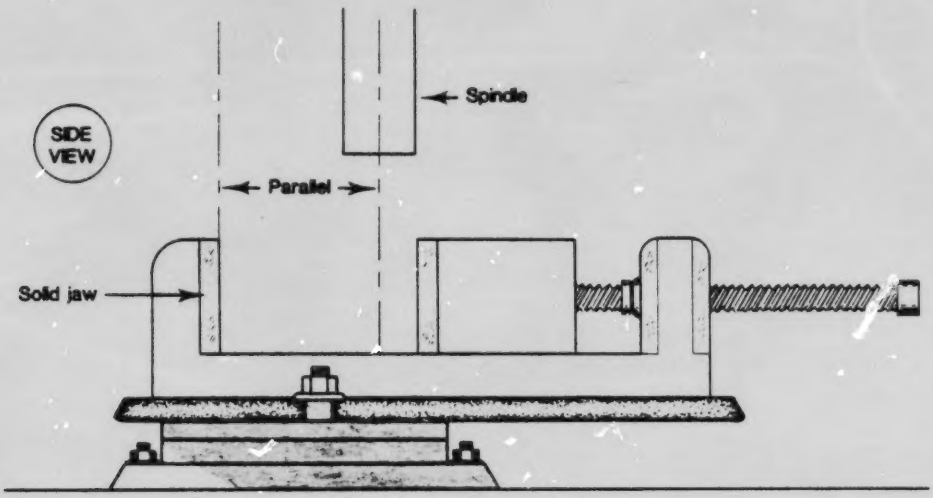
Then, he/she checks the centers of the lathe again with the dial indicator.
The centers of the lathe must be exactly straight.

Remember, to align 2 parts of a machine tools means:

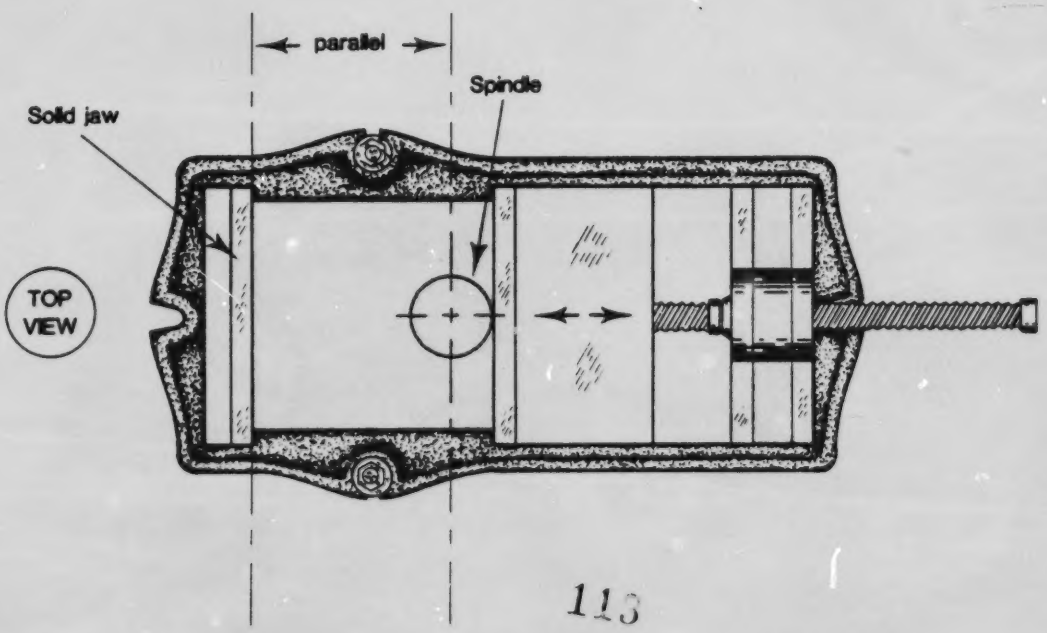
to make 2 parts of a machine tool line up exactly straight.
OR
to make 2 parts of the machine tool line up exactly parallel.

ALIGNING THE VISE AND THE SPINDLE OF THE VERTICAL MILL

The machinist must align the solid jaw of the vise and the spindle of the vertical mill to make accurate parts.
Here, align means to make 2 parts of a machine tool exactly parallel.



On the vertical mill, the solid jaw of the vise and the spindle must be exactly parallel.
The machinist must align the solid jaw of the vise to the spindle.
He/she uses a dial indicator to align the solid jaw of the vise to the spindle.



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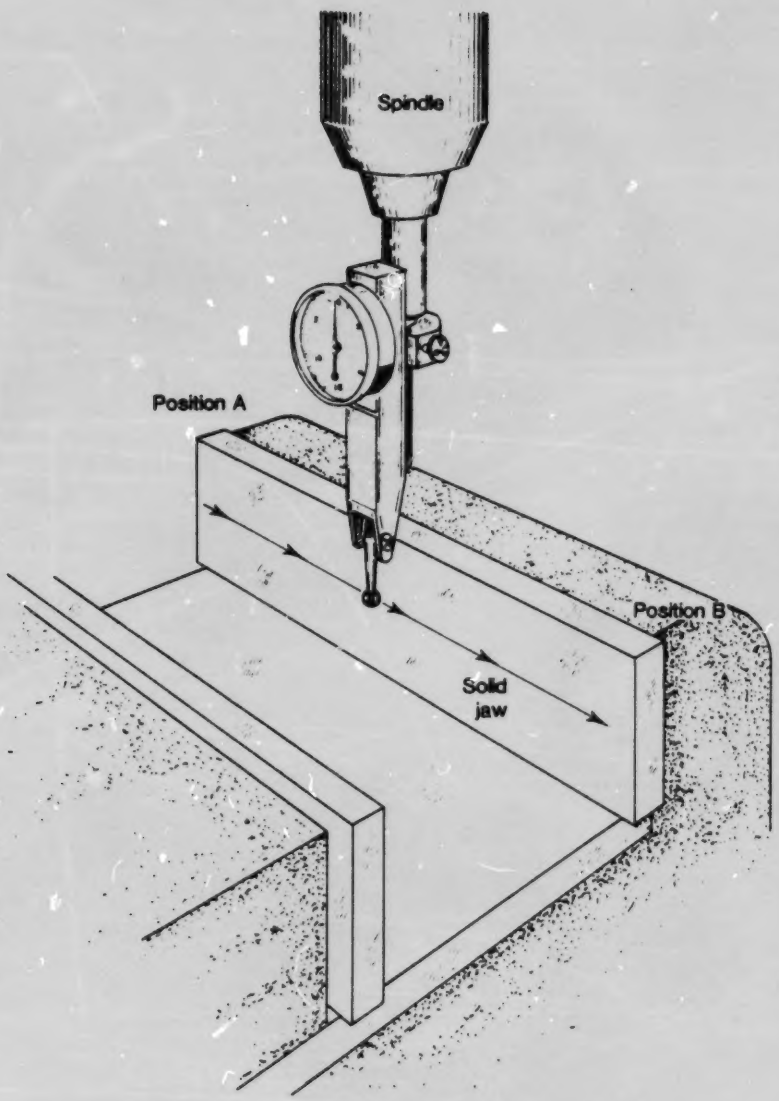


On this dial indicator, each line is .0005" and the range is .030"

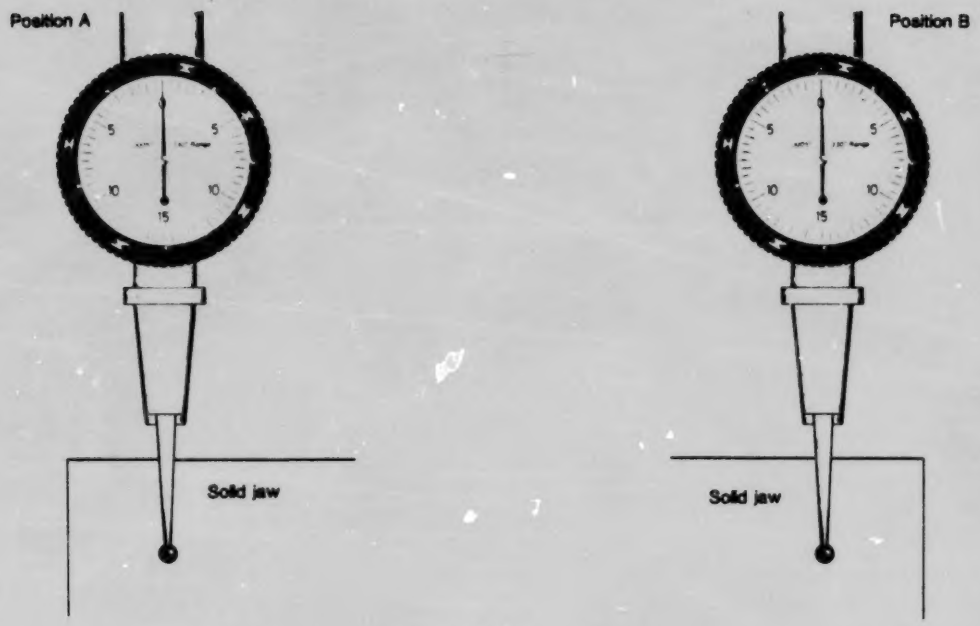
First, the machinist sets up a dial indicator on the spindle.

Then, he/she moves the vise to put the plunger of the dial indicator on one end of the solid jaw of the vise.

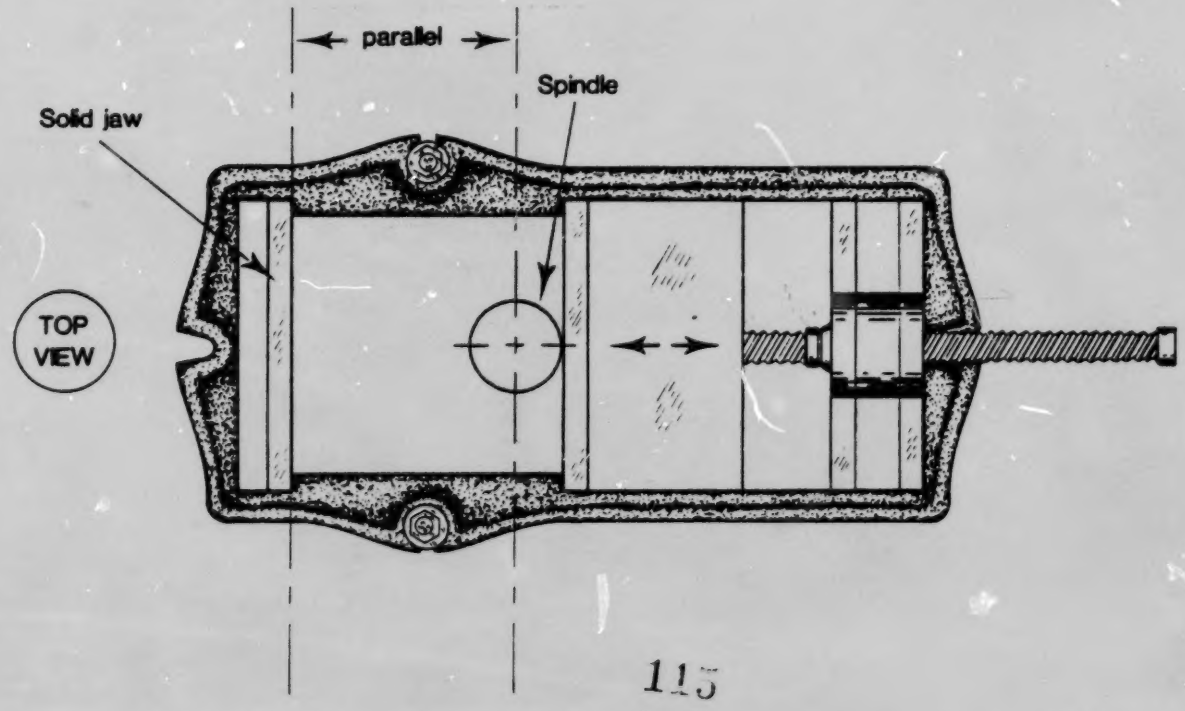
Next, he/she sets a zero point. (Position A)

Then, he/she moves the vise until the plunger is at the other end of the solid jaw of the vise. (Position B)

Last, he/she reads the dial to check if the solid jaw of the vise and the spindle are parallel.



If the needle on the dial does not move from the zero point, the machinist knows the solid jaw of the vise and the spindle are parallel.
He/she does not have to align the solid jaw of the vise to the spindle.



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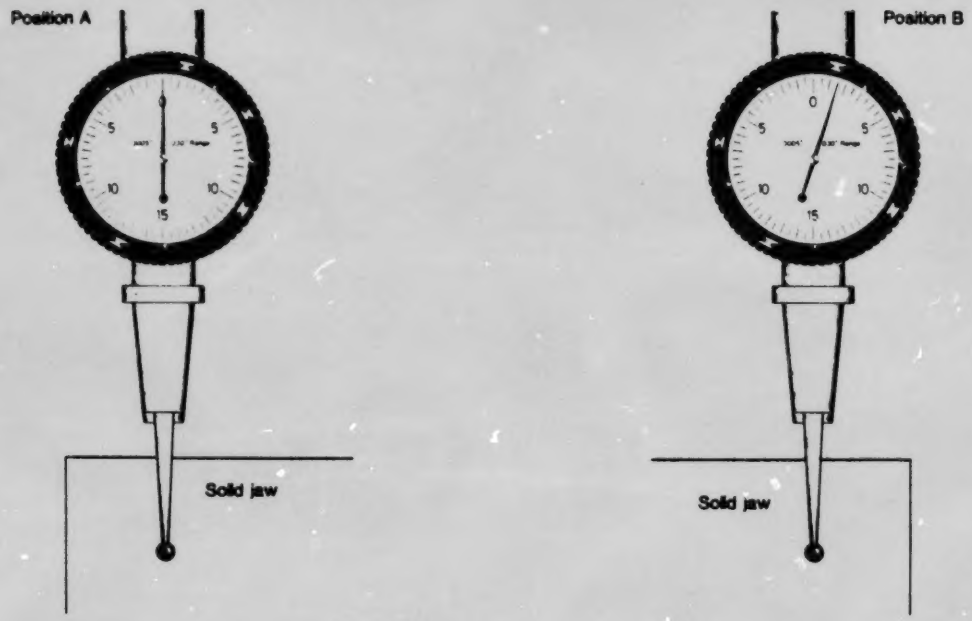
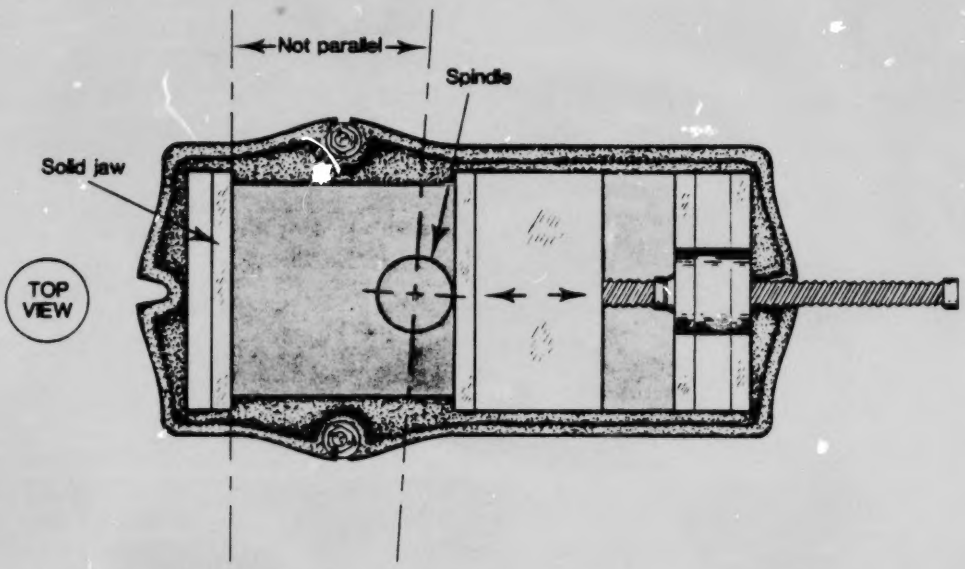


If the needle on the dial moves from the zero point, the machinist knows the solid jaw of the vise and the spindle are not parallel.
He/she must align the solid jaw of the vise to the spindle.



He/she must adjust the vise to move the solid jaw of the vise.

He/she adjusts the vise.

Then, he/she checks the solid jaw of the vise and the spindle again with the dial indicator.
The solid jaw of the vise and the spindle of the vertical must be exactly parallel.

You will practice how to align the centers of the lathe and how to align the solid jaw and spindle of the vertical mill in the shop.

CARE OF MEASUREMENT TOOLS

These rules will help you make accurate measurements and accurate parts without damage to measurement tools.

Employers will want you to use measurement tools carefully and correctly.

GENERAL RULES

1. Do not drop measurement tools.
2. Do not carry measurement tools with other tools. You will drop or scratch the measurement tools.
3. Do not put measurement tools in a pile of tools.
4. Do not try to measure moving parts.
5. Do not remove rust or stains on measurement tools with abrasive cloth.
6. Wipe off measurement tools and then put the measurement tools away.

CARE OF DIAL INDICATORS

1. Do not put oil on any part of the dial indicator.
2. Do not rapidly move the plunger in and out of the dial indicator. This will break the dial indicator.
3. Do not try to fix or repair a dial indicator.

Machine Shop Fundamentals

5A

UNIT 5: Blueprint Reading

LESSON 5A: Introduction to Blueprint Reading

OBJECTIVES:

1. The student will write the correct definition of a blueprint.
2. The student will write the 2 main kinds of technical information on a blueprint.
3. The student will match the name of a dimension to a picture of that dimension.
4. The student will write the correct blueprint abbreviation for diameter and the correct blueprint symbol for diameter.
5. The student will write the correct blueprint abbreviation for radius.
6. The student will write the correct dimensions of a finished part from a picture of the finished part.

PROCEDURES:

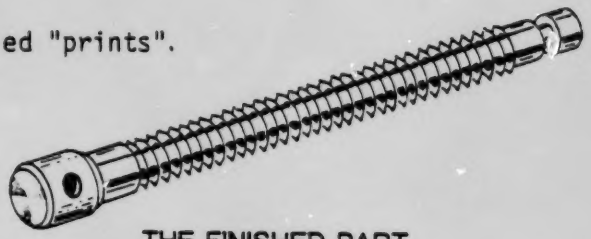
1. Read the Objectives.
2. Read the Lesson.
3. Watch the Slide Show.
4. Watch the teacher's Demonstration.
5. Do the Study Questions.
6. Do the Worksheets.
7. Do the Review Questions.
8. Do the Self-Test.

REFERENCES:

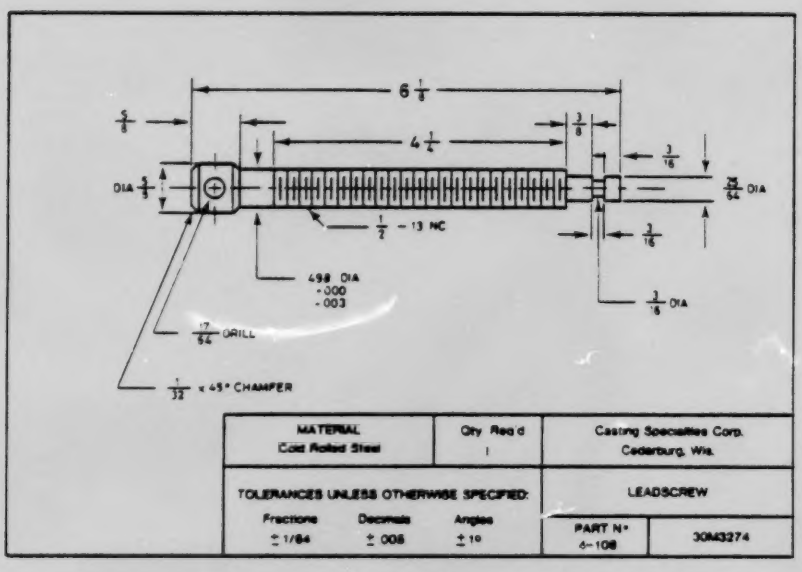
INTRODUCTION

What is a blueprint?

A BLUEPRINT is a picture of a finished part.
First, an engineer designs the finished part.
Then, a drafter draws a picture or illustration of the finished part.
Finally, the drafter makes copies of the picture or illustration of the finished part.
The copies of the picture or illustration of the finished part are called blueprints.
Some blueprints have blue lines.
Some blueprints have brown or black lines.
In the machine shop, blueprints are often called "prints".



THE FINISHED PART



THE BLUEPRINT

A blueprint gives 2 main kinds of technical information:

1. The exact shape of the finished part.
2. The exact sizes of the finished part.

A blueprint also gives other technical information to make the finished part.

A machinist reads or interprets a blueprint.
He/she reads the technical information on a blueprint to make a finished part.
He/she reads the blueprint to lay out the part.
He/she reads the blueprint to set up the machine tool.
He/she reads the blueprint to check the sizes of the finished part.

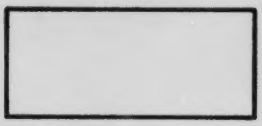
SHAPES

A blueprint shows the shape of a finished part.

This is a square.
A square has 4 equal sides.
(Equal means the same.)
Each corner has 90°

A SQUARE

This is a rectangle.
A rectangle has 2 pairs of equal sides.
Each corner has 90°

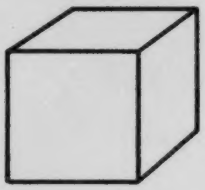


A RECTANGLE

This is a circle.
A circle is round.

A CIRCLE

A SQUARE PART

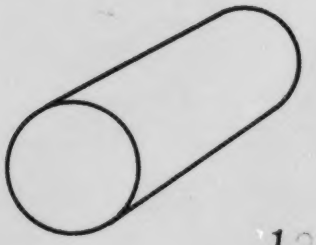


The shape of this part is square.
This part is square.

A RECTANGULAR PART

The shape of this part is rectangular.
This part is rectangular.

A ROUND PART



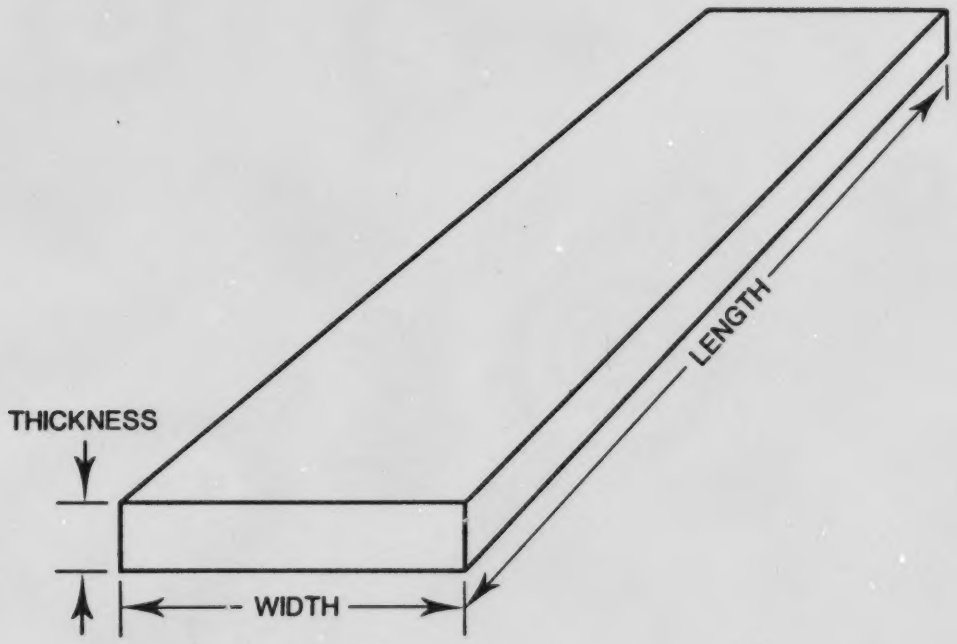
The shape of this part is round or cylindrical.
This part is round or cylindrical.

SIZES AND DIMENSIONS

A blueprint shows the exact sizes of a finished part.
The exact sizes of a finished part are called dimensions or specifications.
Remember, specifications are sometimes called "specs" in the machine shop.
Most parts have several dimensions.
There are 6 main kinds of dimensions:

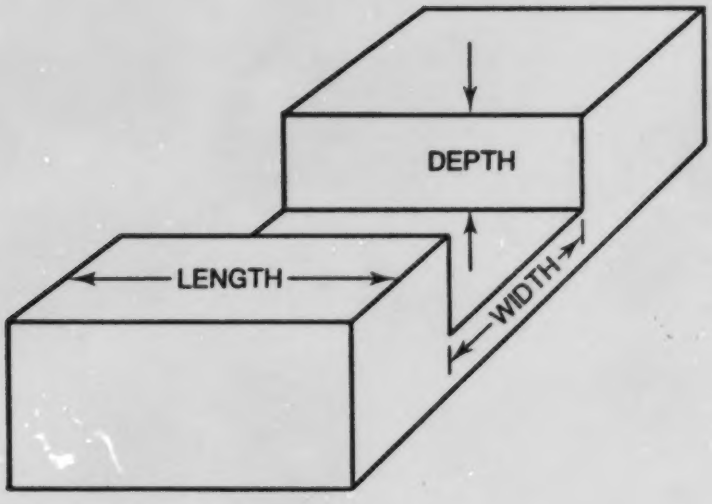
LENGTH
WIDTH
THICKNESS
DEPTH
DIAMETER
RADIUS

A machinist measures the length, width, and thickness of many parts.



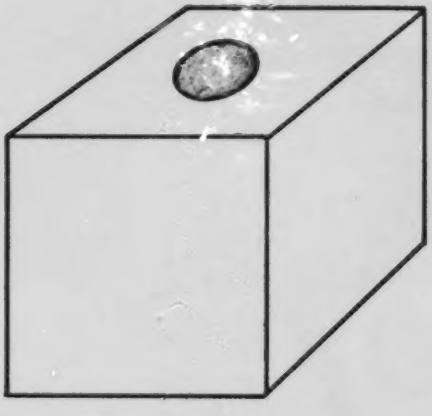
On the outside dimensions of a finished part, the length is the largest dimension.
On the outside dimensions of a finished part, the width is smaller than the length.
On the outside dimensions of a finished part, the thickness is smaller than the width and length.
On the outside dimensions of a finished part, the thickness is the smallest dimension.

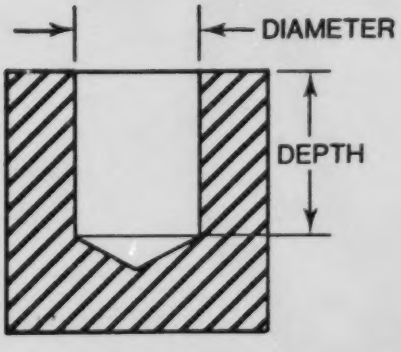
This finished part has a SLOT.
A machinist measures the length, width, and depth of a slot.



With slots, the width of a slot can be larger than the length of the slot.

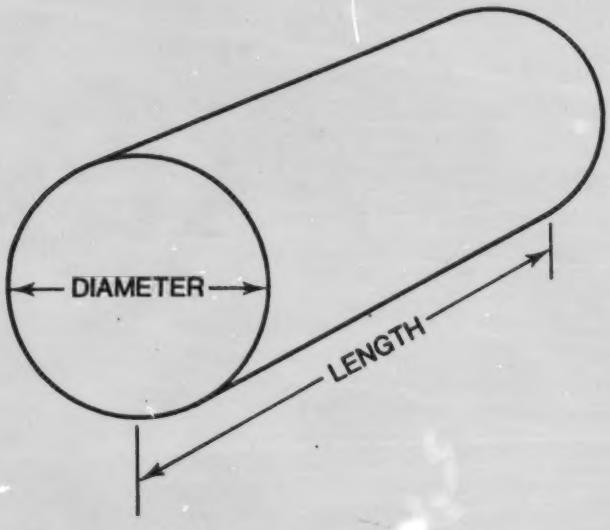
This finished part has a BLIND HOLE.
A blind hole does not go completely through the part.
A machinist measures the depth and diameter of a blind hole.





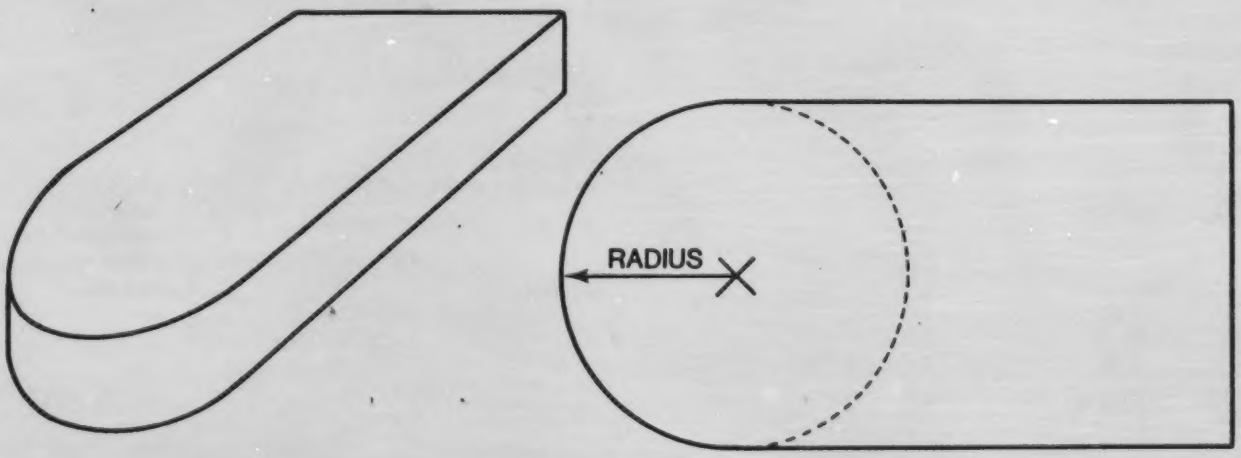
A diameter is the distance from one edge of a circle to the other edge.
The diameter goes through the center of the circle.
Blueprints use the abbreviation DIA or the symbol ϕ for diameter.

The machinist measures the diameter and length of cylindrical (round) parts.



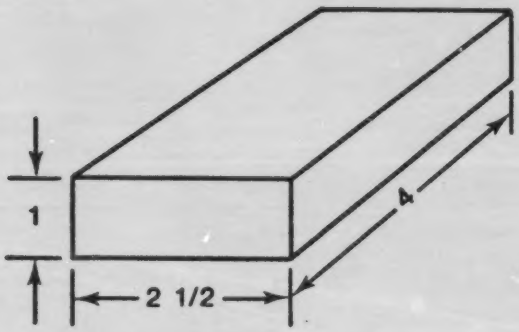
A diameter is the distance from one edge of a circle to the other edge.
The diameter goes through the center of the circle.
Blueprints use the abbreviation DIA or the symbol ϕ for diameter.

Sometimes, a machinist cannot measure the diameter or length of a curved dimension on a part.
Then, he/she measures the radius of the curved dimension on the part.

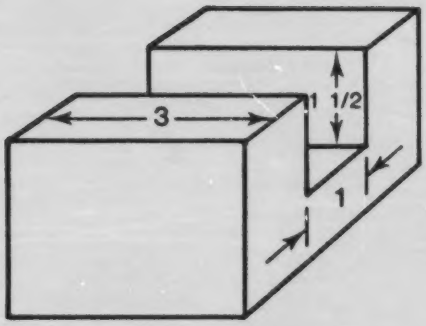


In math, a radius is the distance from the center of a circle to the edge of the circle.
Blueprints use the abbreviation R for radius.

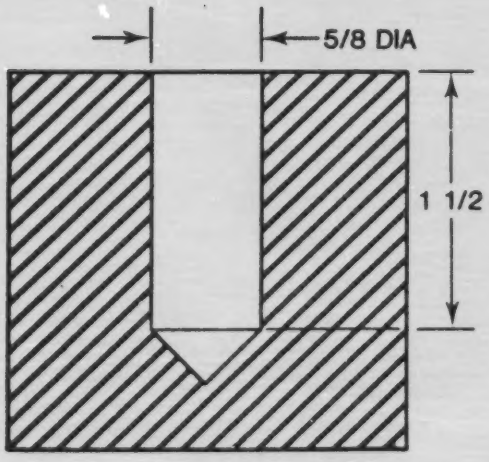
EXAMPLES



This is a rectangular part.
The length of the part is 4"
The width of the part is 2 $\frac{1}{2}$"
The thickness of the part is 1"



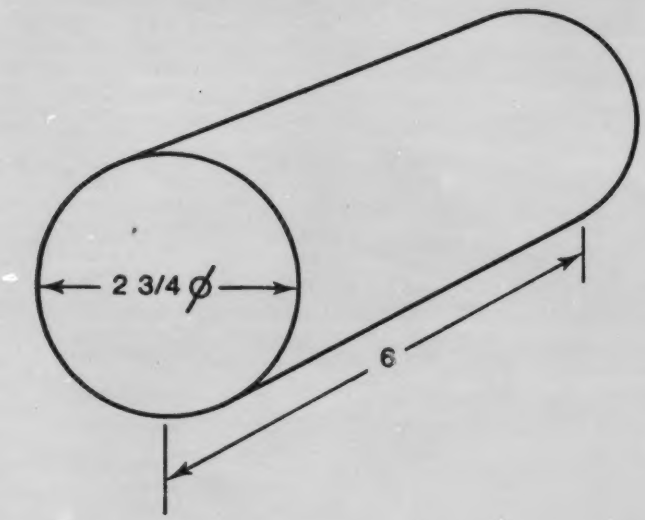
This is a rectangular part.
This part has a slot.
The length of the slot is 3"
The width of the slot is 1"
The depth of the slot is 1 $\frac{1}{2}$"



This is a square part.
This part has a blind hole.
The depth of the blind hole is 1 $\frac{1}{2}$"
The diameter of the blind hole is $\frac{5}{8}$"
Remember, blueprints use DIA or ϕ for diameter.

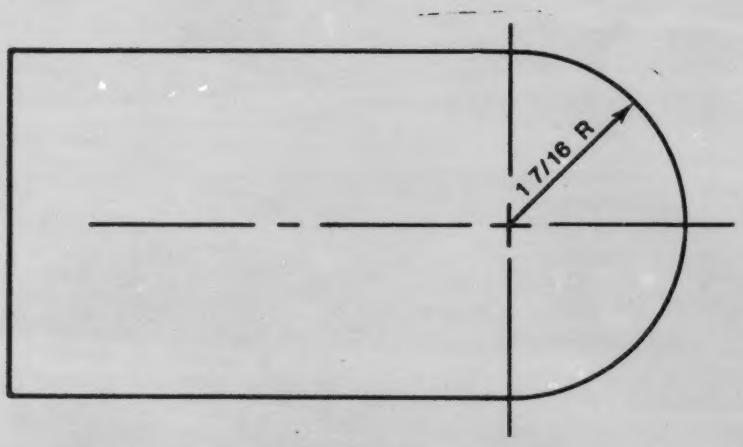
This is a cylindrical part.
The length of the part is 6"
The diameter of the part is 2 $\frac{3}{4}$"

Remember, blueprints use DIA or ϕ for diameter.



This is a rectangular part with a curved end.
The radius of the curved end is 1 $\frac{7}{16}$"

Remember, blueprints use R for radius.



SUMMARY

A blueprint is a picture of a finished part.

A blueprint gives 2 main kinds of technical information:

1. The exact shape of the finished part
2. The exact sizes of the finished part

The exact sizes of a finished part are called dimensions or specifications.

There are 6 main kinds of dimensions:

Length
Width
Thickness
Depth
Diameter
Radius

On a blueprint, the abbreviation for diameter is DIA.

On a blueprint, the symbol for diameter is ∅
On a blueprint, the abbreviation for radius is R.

Machine Shop Fundamentals

5B

UNIT 5: Blueprint Reading

LESSON 5B: Basic Views

OBJECTIVES:

1. The student will write the correct definition of a blueprint.
2. The student will write the names of the 6 basic views.
3. The student will write the name of each view in the correct position on a blueprint.
4. The student will match a finished part to the blueprint of that finished part.

PROCEDURES:

1. Read the Objectives.
2. Read the Lesson.
3. Watch the teacher's Demonstration.
4. Do the Study Questions.
5. Do the Worksheets.
6. Do the Review Questions.
7. Do the Self-Test.

REFERENCES:

INTRODUCTION

A blueprint is a picture of a finished part.

A blueprint gives 2 main kinds of technical information:

1. The exact shape of the finished part
2. The exact sizes or dimensions of the finished part

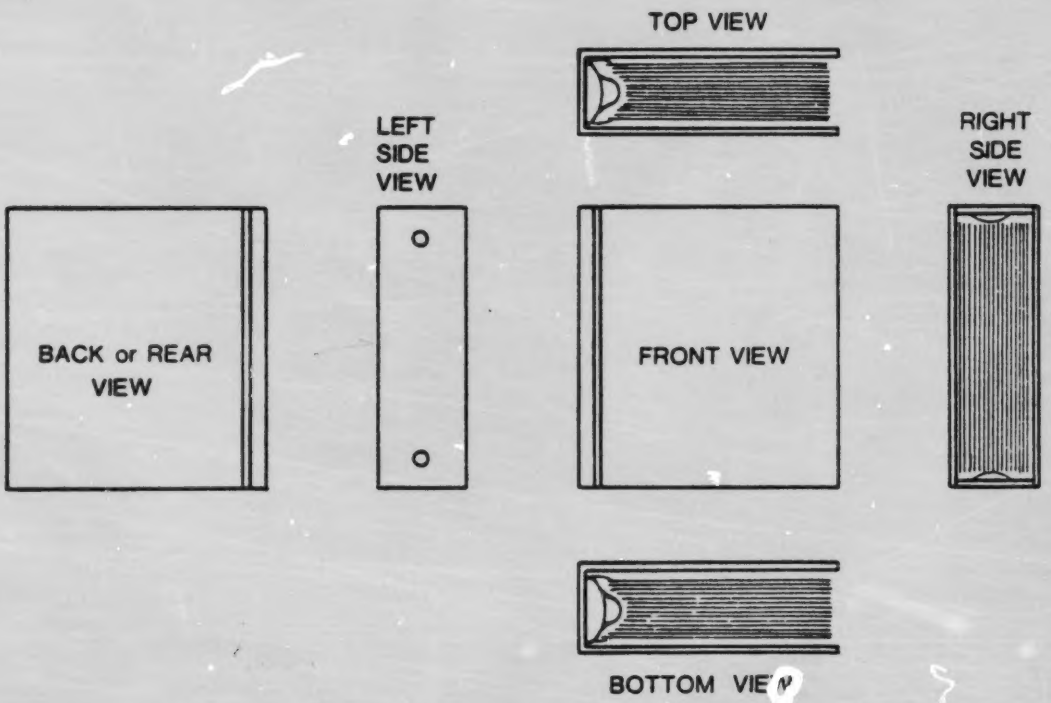
A blueprint also gives other technical information to make the finished part.

A machinist reads or interprets a blueprint to make the finished part.

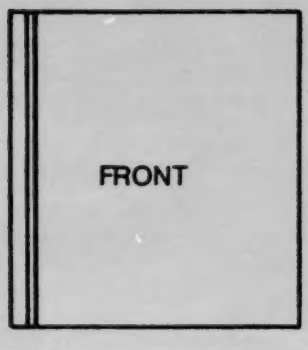
VIEWS

To give the exact shape of the finished part and the exact dimensions of the finished part, the blueprint shows different VIEWS of the finished part.

Imagine that your notebook is a finished part.
Here are the views of your notebook on a blueprint.

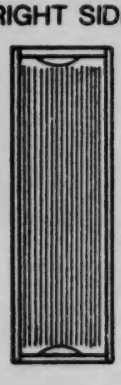


You can look at the front of the notebook, the top of the notebook, the bottom of the notebook, the right side of the notebook, the left side of the notebook, and the back or rear of the notebook.



You can see a certain shape, certain dimensions, and certain surfaces when you look at the front of the notebook/finished part.
You only see the shape, dimensions, and surfaces of the front of the notebook/finished part.

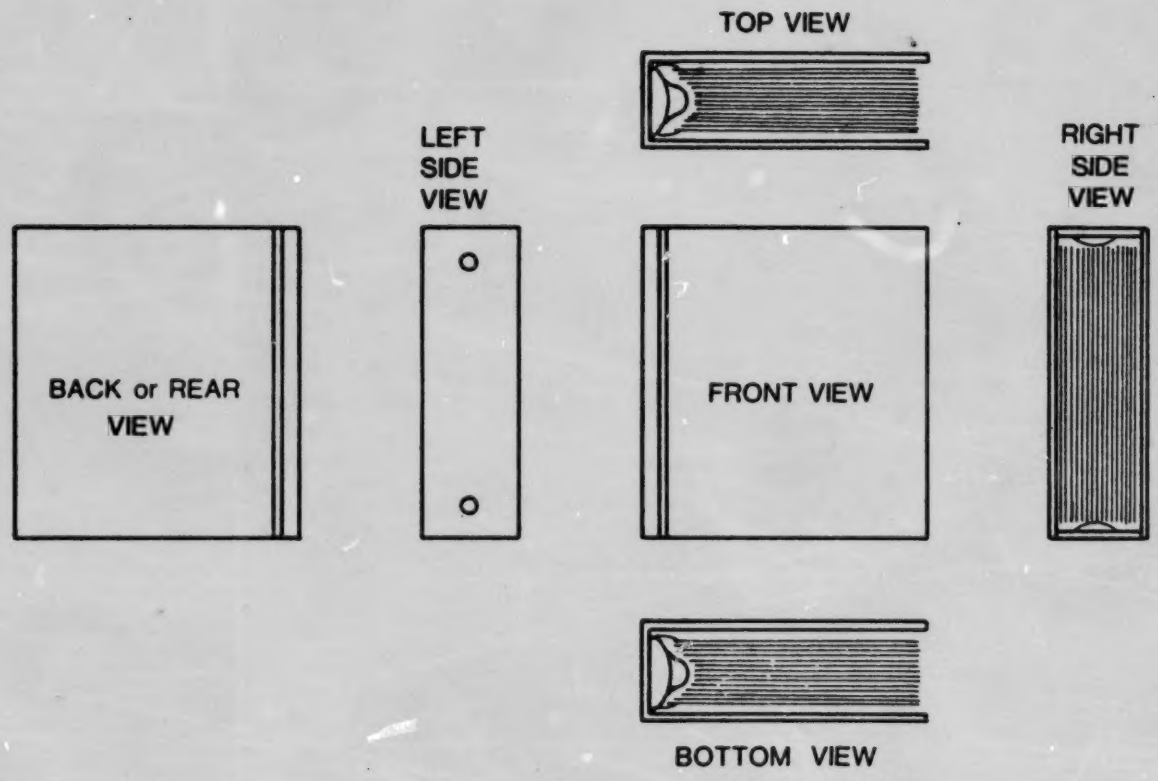
You look at the top of the notebook to see the shape, dimensions, and surfaces of the top of the notebook/finished part.



You look at the right side of the notebook to see the shape, dimensions, and surfaces of the right side of the notebook/finished part.

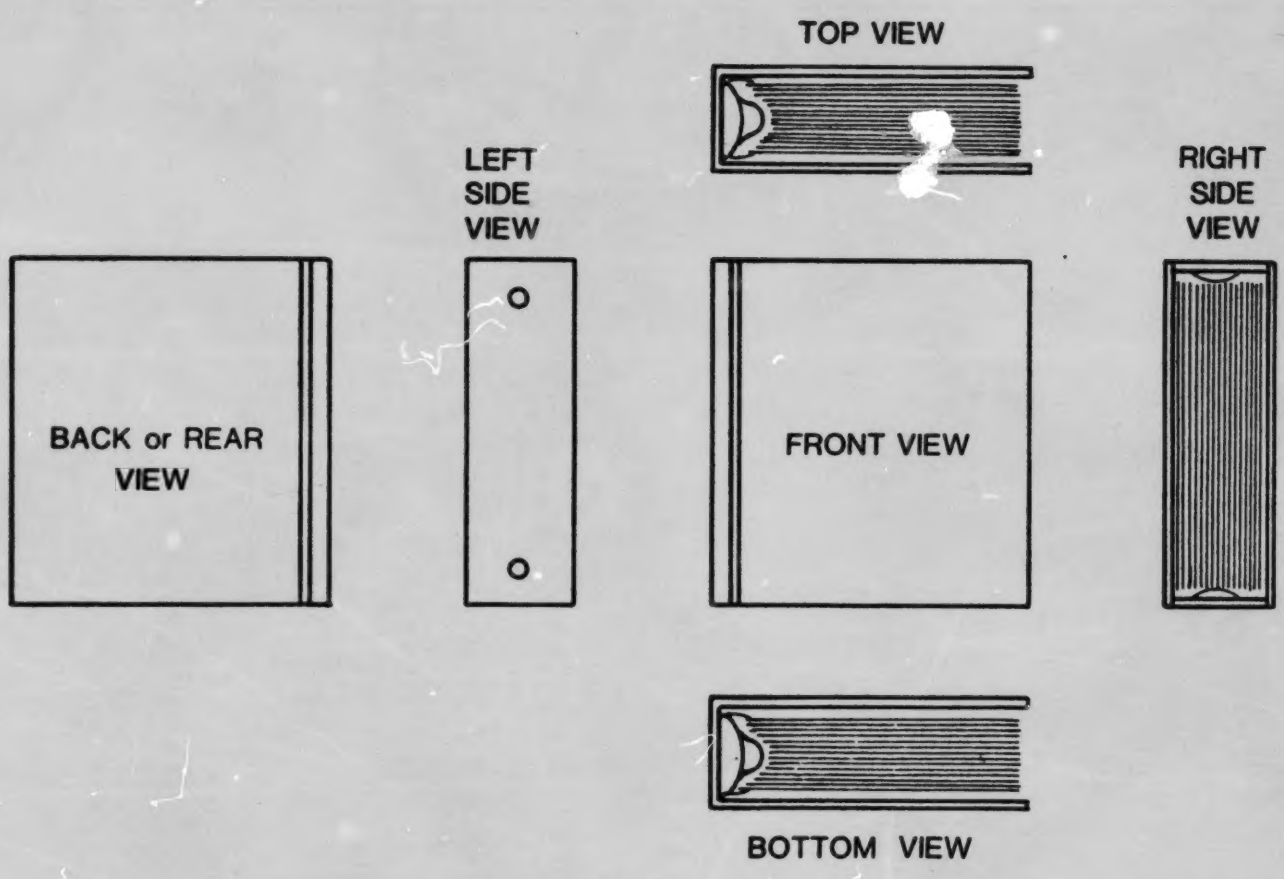
On blueprints, there are 6 basic views:

THE FRONT VIEW
THE TOP VIEW
THE RIGHT SIDE VIEW
THE LEFT SIDE VIEW
THE REAR VIEW
THE BOTTOM VIEW



The FRONT VIEW shows the front of the finished part.
The TOP VIEW shows the top of the finished part.
The RIGHT SIDE VIEW shows the right side of the finished part.
The LEFT SIDE VIEW shows the left side of the finished part.
The REAR VIEW shows the back or rear of the finished part.
The BOTTOM VIEW shows the bottom of the finished part.

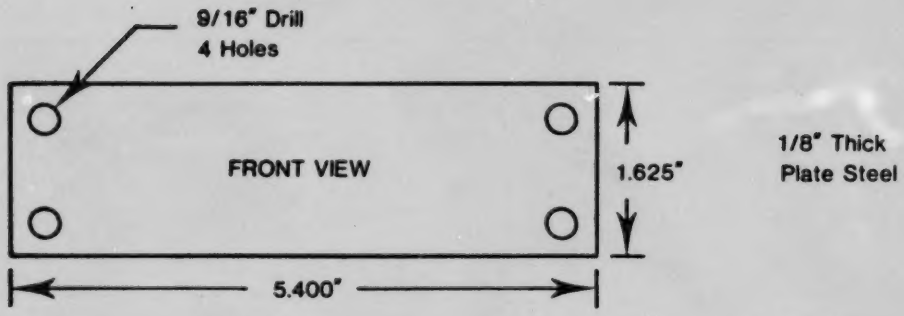
The POSITION OF THE VIEWS is always the same on all blueprints.



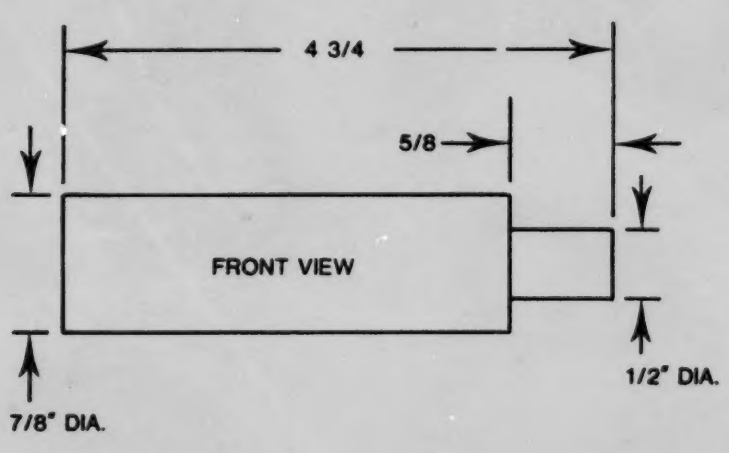
All blueprints have a front view of the finished part.
The front view is the most important view.
The drafter chooses the front of the finished part and draws the front view.
Then, he/she draws the other views.

Sometimes, a finished part needs only 1 view on the blueprint.
Sometimes, a finished part needs 2 views on the blueprint.
Sometimes, a finished part needs 3 views on the blueprint.
Most blueprints have 2 or 3 views.
Sometimes, a finished part needs 4 or more views on the blueprint.
Remember, all blueprints have a front view of the finished part.

BLUEFRINTS WITH 1 VIEW

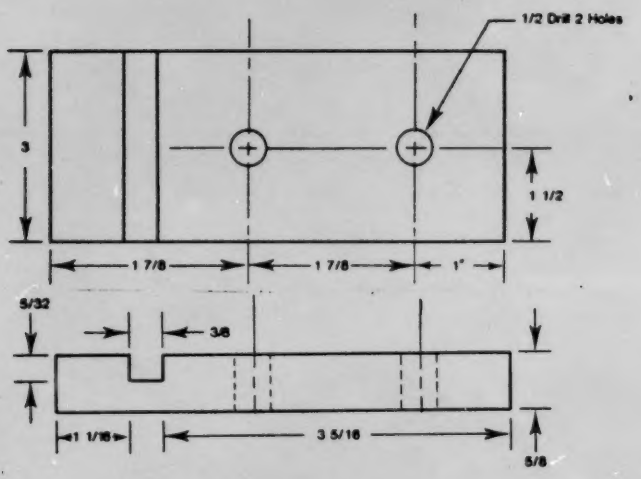


The shape of this finished part is rectangular.
This finished part has 4 holes.
The length of this finished part is 5.400"
The width of this finished part is 1.625"
The thickness of this finished part is $\frac{1}{8}$"

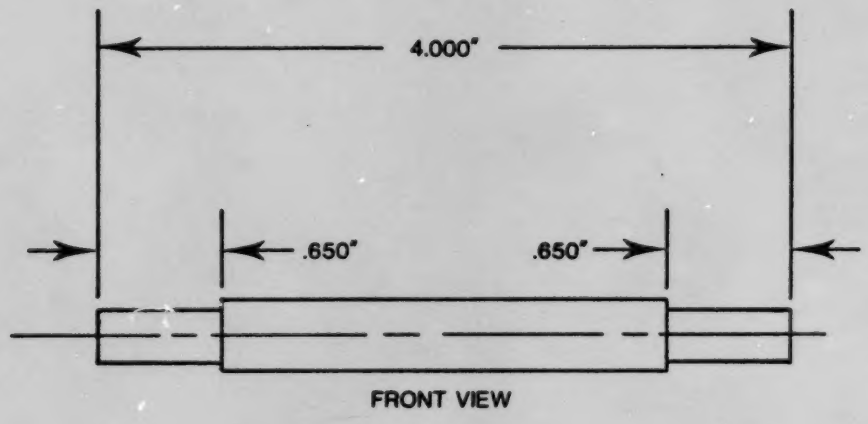


The shape of this finished part is round (cylindrical).
The machinist reads DIA and knows this finished part is round (cylindrical)
The large diameter of this finished part is $\frac{7}{8}$"
The small diameter of this finished part is $\frac{1}{2}$"
The length of this finished part is 4 $\frac{3}{4}$"

BLUEPRINTS WITH 2 VIEWS

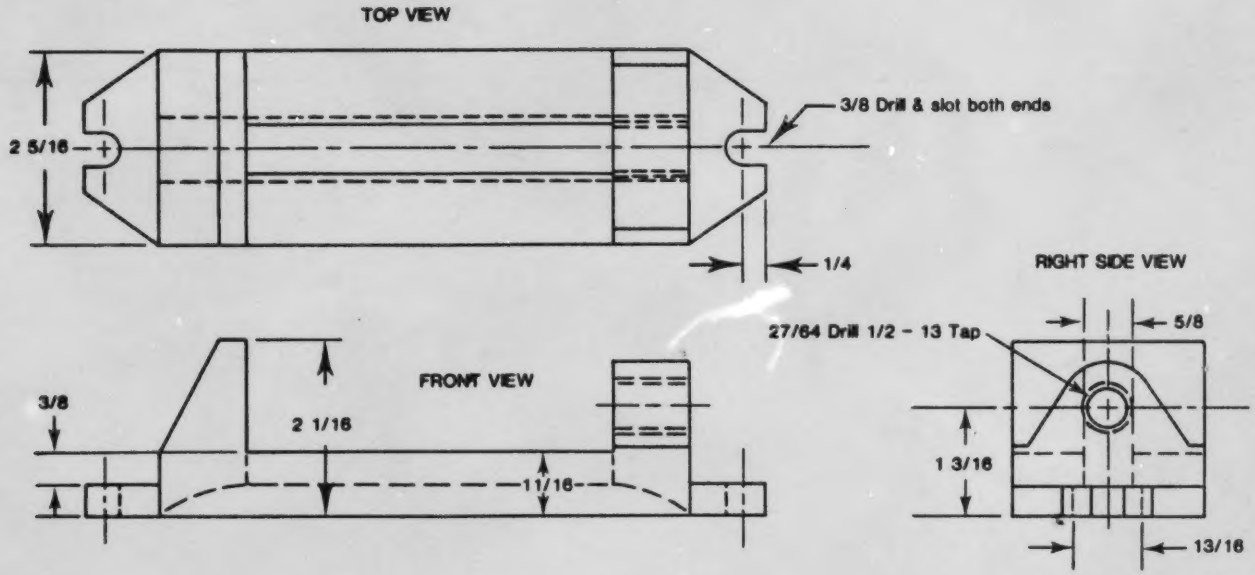


The shape of this finished part is rectangular.
This finished part has a slot.
The length of this slot is 3"
The width of this slot is $\frac{3"}{8}$
The depth of this slot is $\frac{5"}{32}$

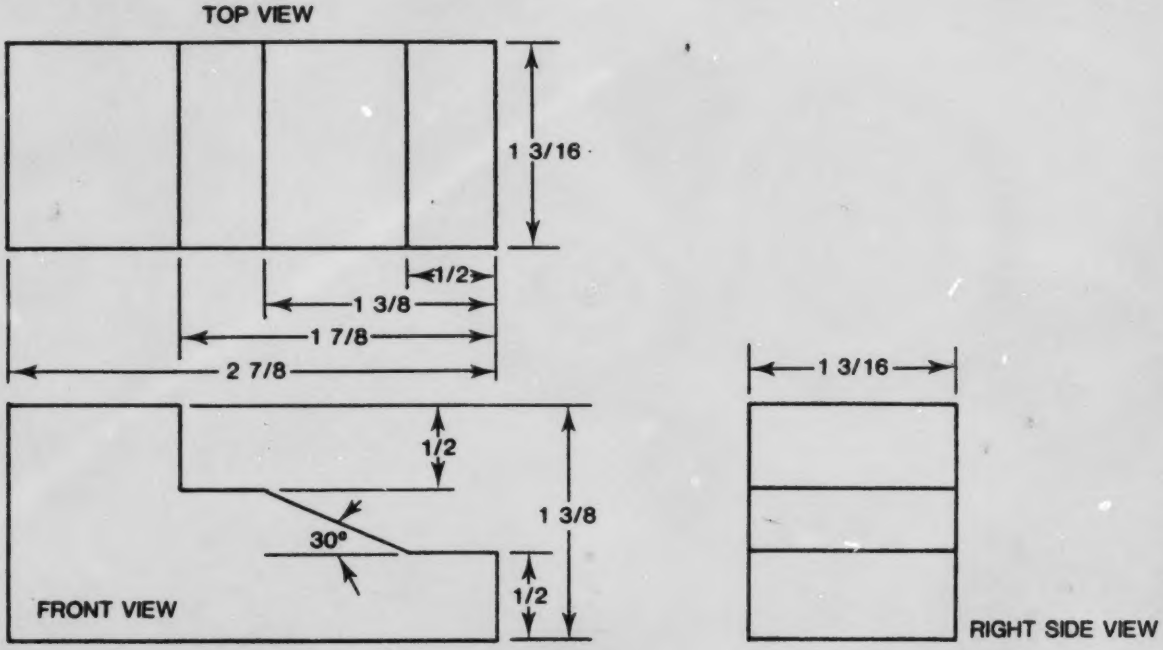


The shape of this finished part is round (cylindrical).
The machinist reads DIA and knows this finished part is round (cylindrical).
The large diameter of this finished part is .398"
The small diameter of this finished part is .300"
The length of this finished part is 4.000"

BLUEPRINTS WITH 3 VIEWS



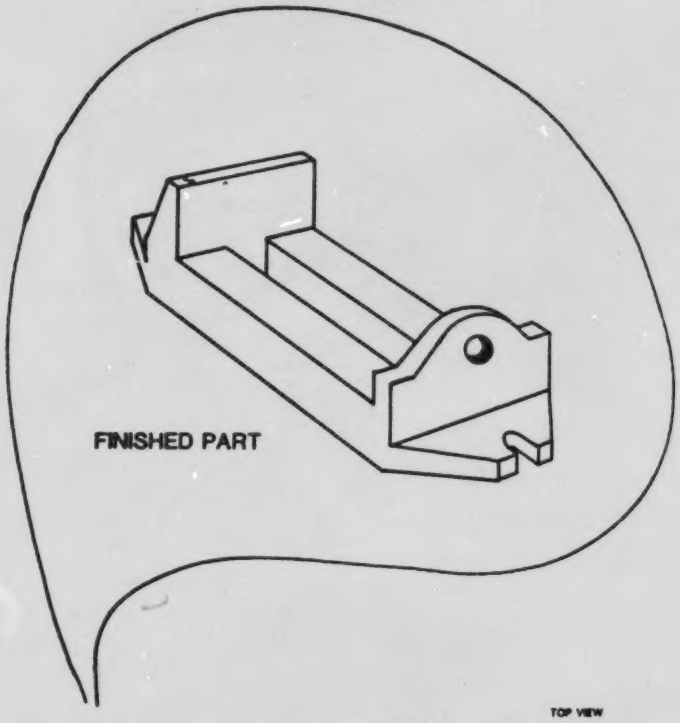
This blueprint shows the front view, top view, and right side view of the finished part.

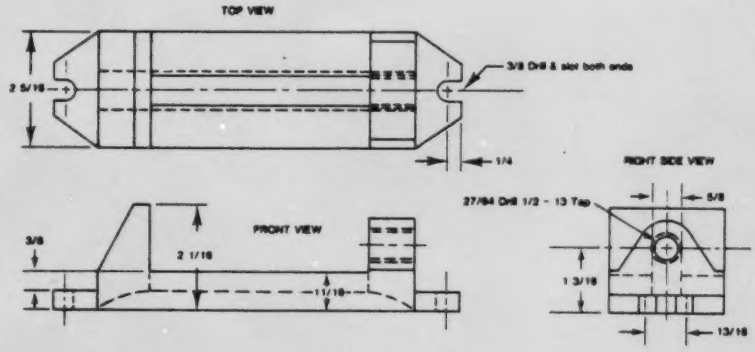


This blueprint shows the front view, top view, and right side view of the finished part.

USING THE VIEWS TO SEE THE FINISHED PART

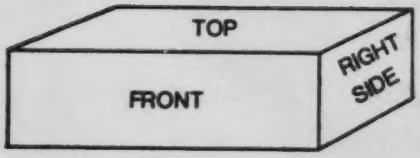
A machinist reads a blueprint to make the finished part.
He/she uses his/her knowledge of views to see the finished part in his/her head.

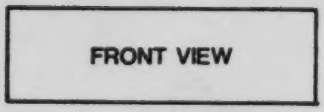


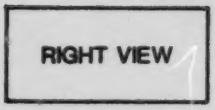


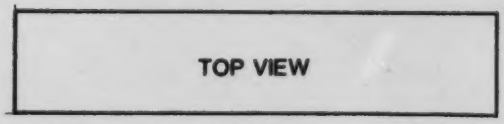
A machinist must study blueprint reading to make accurate parts.
A machinist must practice blueprint reading to make accurate parts.

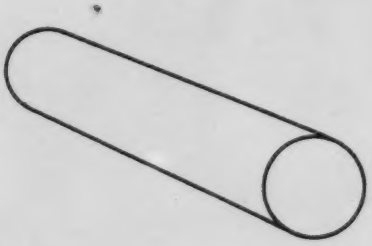
For practice, study the views on these blueprints and finished parts.

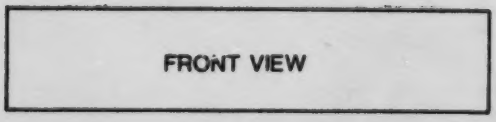


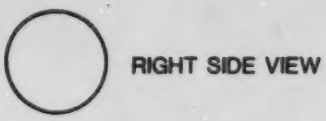


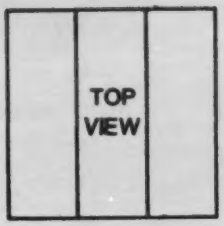


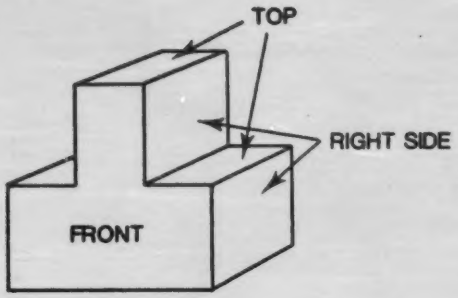




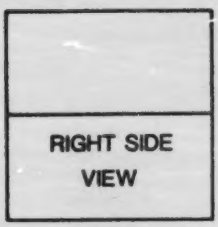


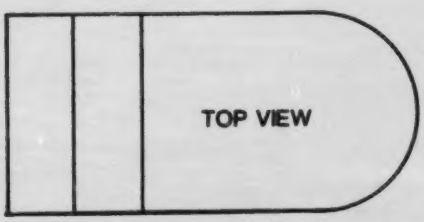


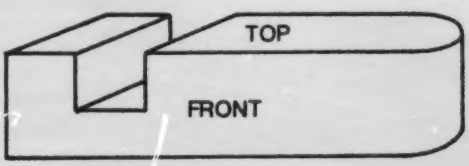

TOP
VIEW

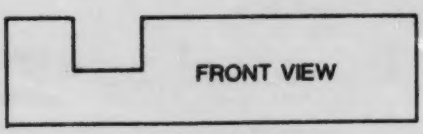

TOP
RIGHT SIDE
FRONT

FRONT VIEW

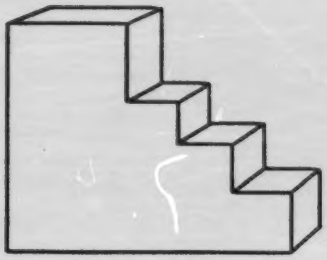

RIGHT SIDE
VIEW

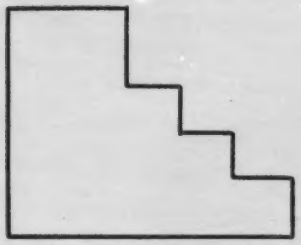

TOP VIEW

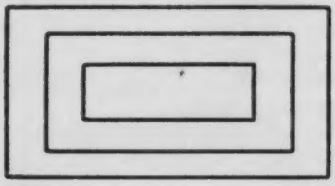

TOP
FRONT

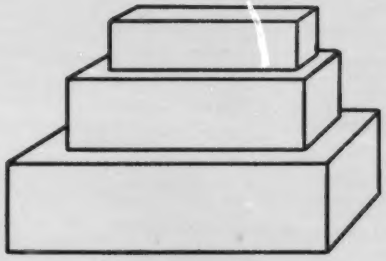

FRONT VIEW

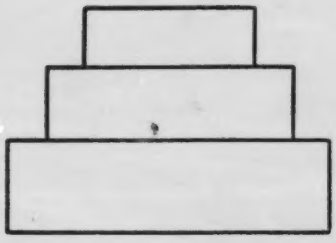
RIGHT SIDE
VIEW

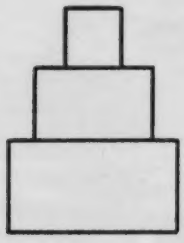










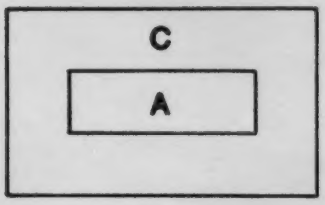


Remember, the front view is the most important view.
Carefully study the views on these blueprints.

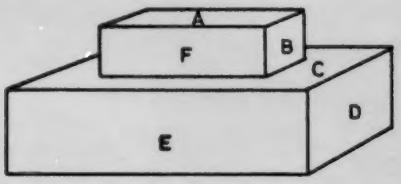
Each view shows certain SURFACES on the finished part.

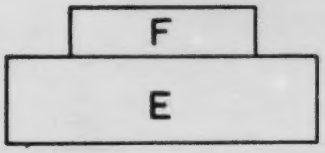
In many textbooks about blueprint reading, surfaces on the finished part are called planes.

For practice, study the views and surfaces of each of these blueprints and each finished part.

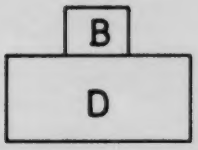


TOP VIEW

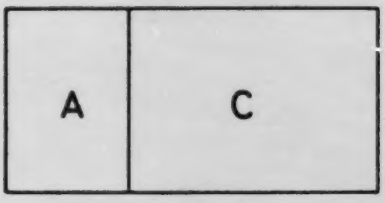




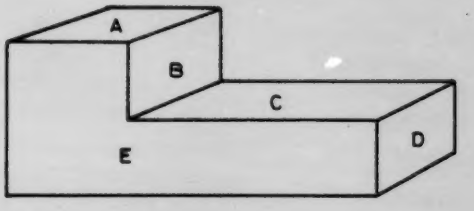
FRONT VIEW

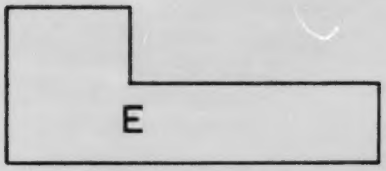


RIGHT SIDE VIEW

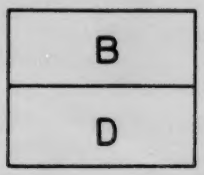


TOP VIEW

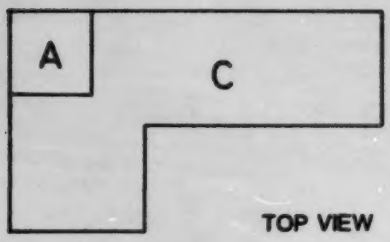




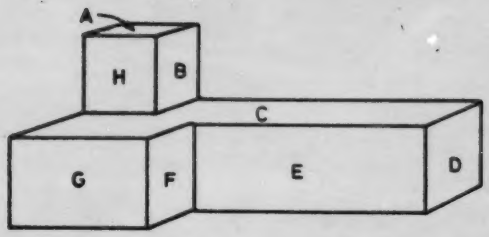
FRONT VIEW

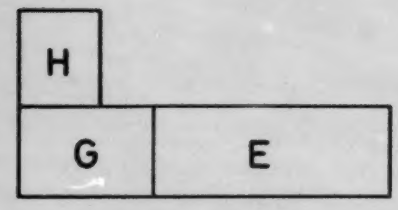


RIGHT SIDE VIEW

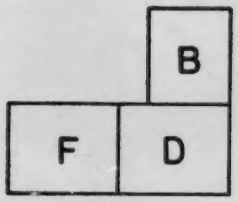


TOP VIEW

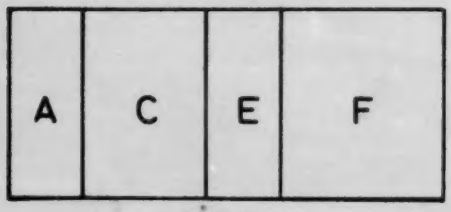




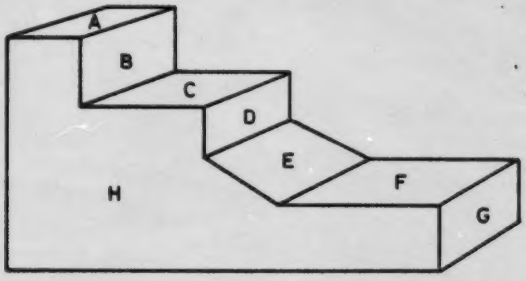
FRONT VIEW

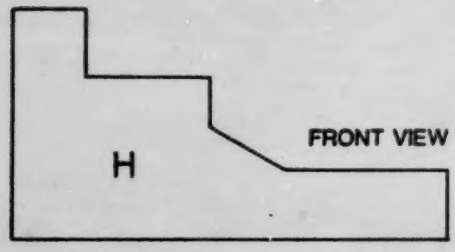


RIGHT SIDE VIEW

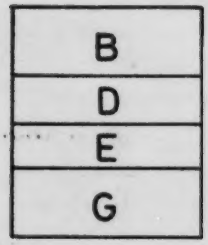


TOP VIEW





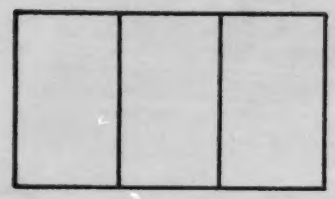
FRONT VIEW



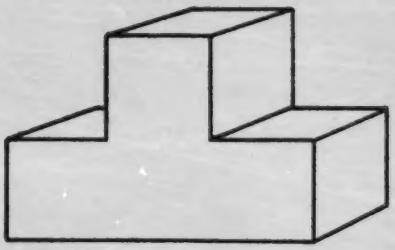
RIGHT SIDE VIEW

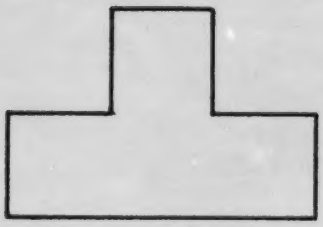
Carefully study the surfaces and views on these blueprints.

For more practice, study the views of these blueprints and the finished part for each one.

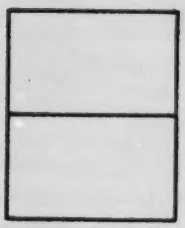


TOP VIEW

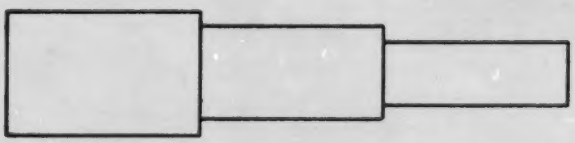




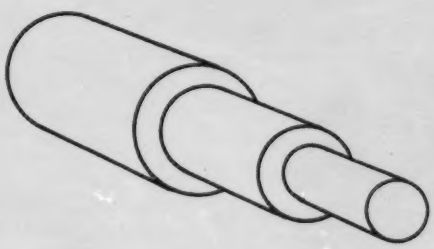
FRONT VIEW

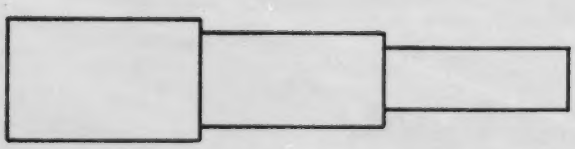


RIGHT SIDE VIEW



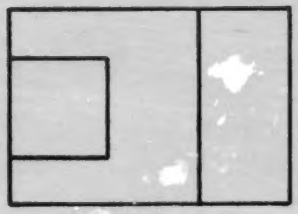
TOP VIEW



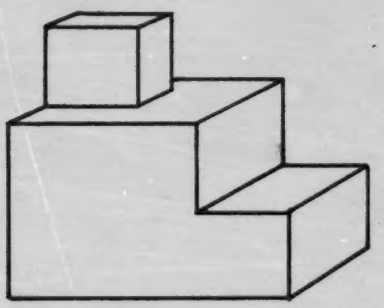


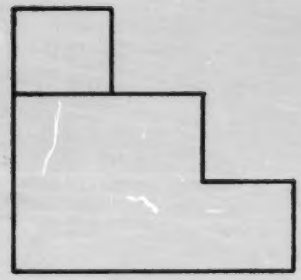
FRONT VIEW

RIGHT SIDE VIEW

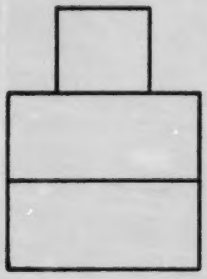


IEW

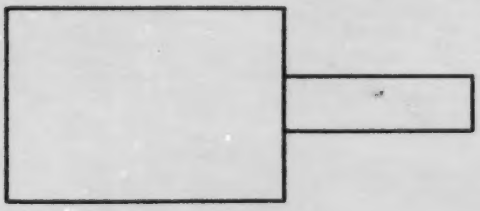




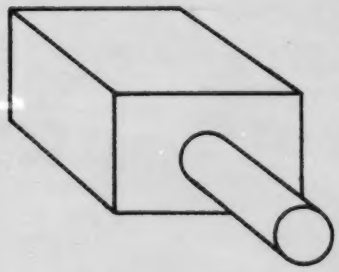
FRONT VIEW

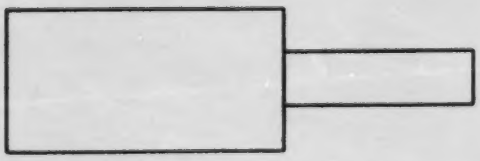


RIGHT SIDE VIEW



TOP VIEW





FRONT VIEW

RIGHT SIDE VIEW

SUMMARY

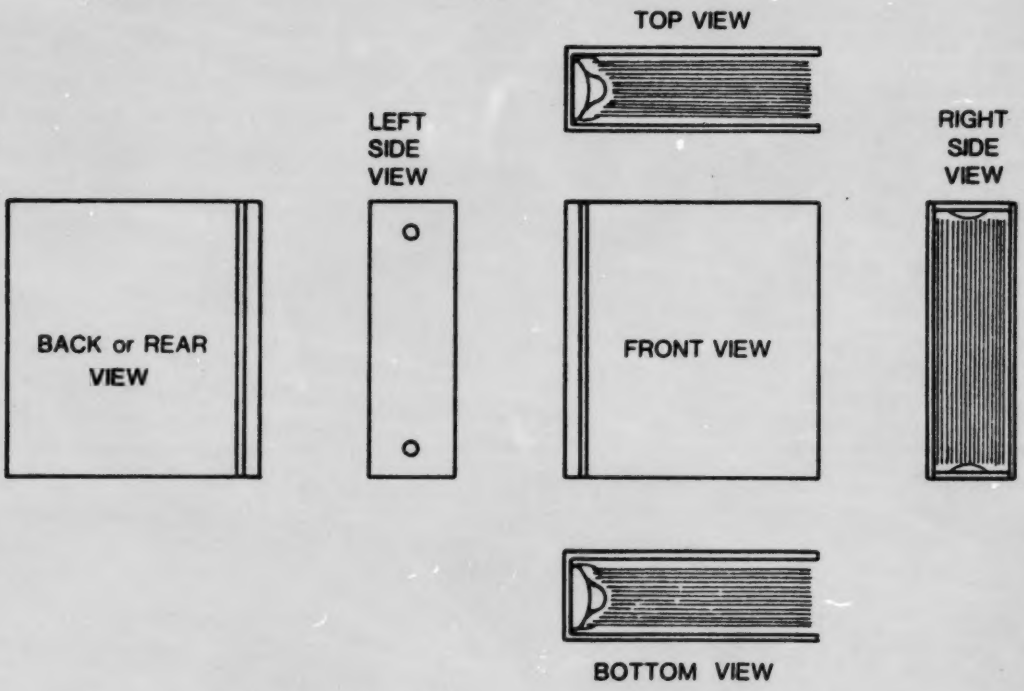
A blueprint is a picture of a finished part.

To give the exact shape of the finished part and the exact dimensions of the finished part, the blueprint shows different views of the finished part.

There are 6 basic views:

THE FRONT VIEW
THE TOP VIEW
THE RIGHT SIDE VIEW
THE LEFT SIDE VIEW
THE REAR VIEW
THE BOTTOM VIEW

The position of the views is always the same on all blueprints.



The front view is the most important view on a blueprint.
Most blueprints have 2 or 3 views.
All blueprints have a front view.
Each view shows a certain shape, certain dimensions, and certain surfaces on the finished part.
A machinist reads a blueprint to make the finished part.
He/she uses his/her knowledge of views to see the finished part in his/her head.

Machine Shop Fundamentals

5C

UNIT 5: Blueprint Reading

LESSON 5C: Lines

OBJECTIVES:

1. The student will write the correct definition of a blueprint.
2. The student will write the names of the 6 basic kinds of lines on a blueprint.
3. The student will match the name of a line to a picture of that line.
4. The student will match the name of a line to the meaning of that line.

PROCEDURES:

1. Read the Objectives.
2. Read the Lesson.
3. Watch the teacher's Demonstration.
4. Do the Study Questions.
5. Do the Worksheets.
6. Do the Review Questions.
7. Do the Self-Test.

REFERENCES:

INTRODUCTION

A blueprint is a picture of a finished part.

A blueprint gives 2 main kinds of technical information:

1. The exact shape of the finished part
2. The exact dimensions of the finished part

A blueprint also gives other technical information to make the finished part.

A machinist reads or interprets a blueprint to make the finished part.

LINES

To give the exact shape of the finished part and the exact dimensions of the finished part, a blueprint uses different kinds of LINES.
The machinist reads or interprets the lines on a blueprint.
The blueprint also shows different views of the finished part.
On a blueprint, the lines and views work together to show the exact shape and exact dimensions of the finished part.

There are 6 basic kinds of lines on blueprints:

1. OBJECT LINES
2. HIDDEN LINES
3. EXTENSION LINES
4. CENTER LINES
5. DIMENSION LINES
6. LEADER LINES

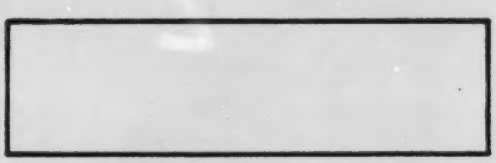
On a blueprint, each kind of line has a special meaning.

OBJECT LINES

What do object lines mean?

OBJECT LINES show the edges of the finished part.
Object lines show the shape of the finished part.

EXAMPLE A



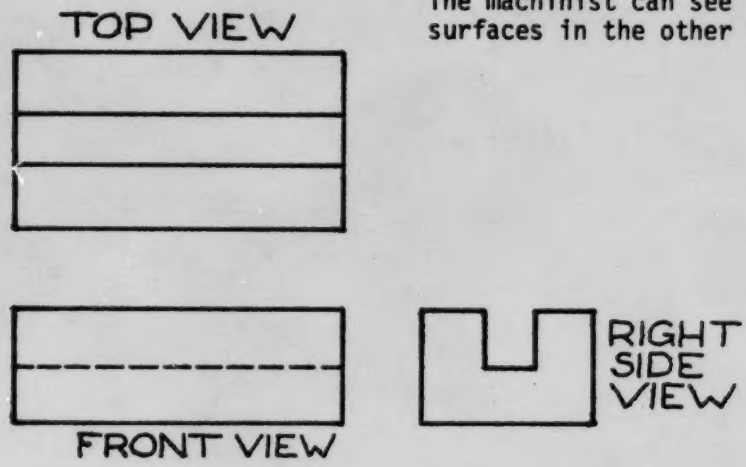
FRONT VIEW

HIDDEN LINES

What do hidden lines mean?

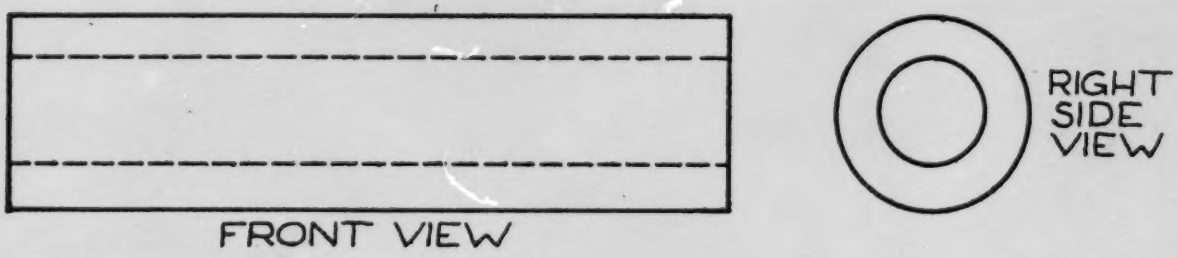
HIDDEN LINES show edges or surfaces that the machinist cannot see in one view.
The machinist can see these edges or surfaces in the other views.

EXAMPLE B



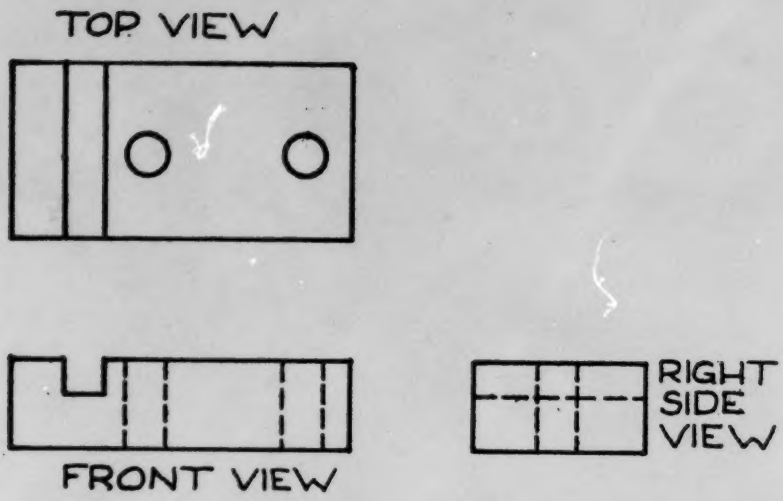
On this blueprint, the finished part has a slot.
The machinist can see the edges of the slot in the top view and in the right side view.
He/she cannot see the edges of the slot in the front view.
He/she must know where the edges of the slot are in the front view.
The hidden line shows the edges of the slot in the front view.
The object lines show the shape of the finished part.

EXAMPLE C



On this blueprint, the finished part has a hole.
The machinist can see the edges of the hole in the right side view.
He/she cannot see the edges of the hole in the front view.
He/she must know where the edges of the hole are in the front view.
The hidden lines show the edges of the hole in the front view.
The object lines show the shape of the finished part.

EXAMPLE D



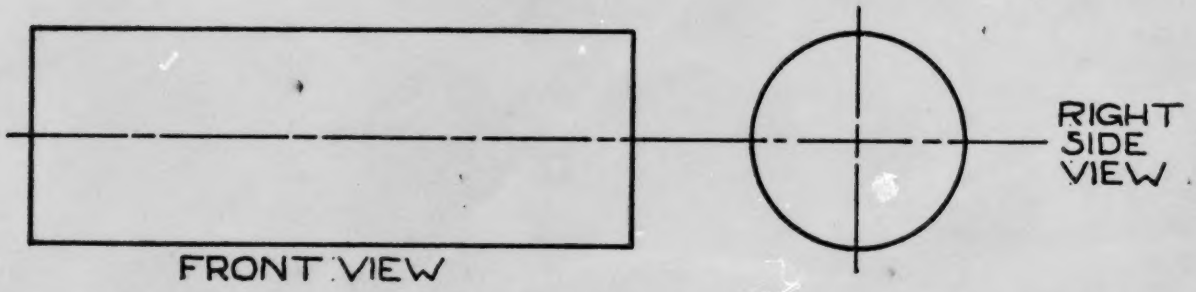
On this blueprint, the finished part has a slot and 2 holes.
The machinist can see the edges of the slot and 2 holes in the top view.
The vertical hidden lines show the edges of the 2 holes in the front view and right side view.
The horizontal hidden line shows the edges of the slot in the right side view.

CENTER LINES

What do center lines mean?

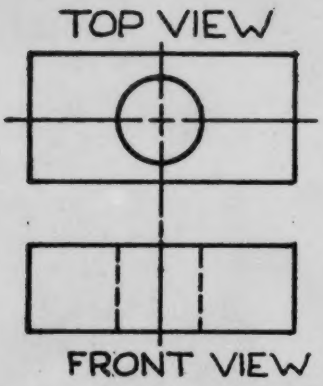
CENTER LINES show the center of the finished part, the center of a hole in the finished part, or the center of a curved edge on the finished part.
The symbol for center lines is ℄

EXAMPLE E



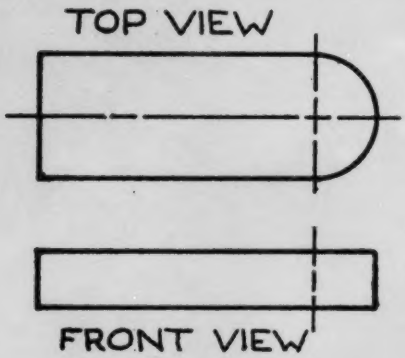
On this blueprint, the shape of the finished part is round (cylindrical).
The center lines show the center of the finished part in the front view and the right side view.

EXAMPLE F



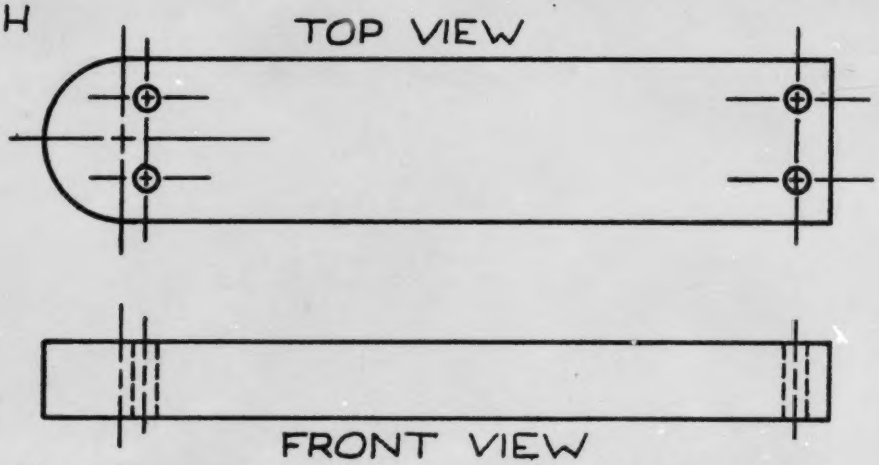
On this blueprint, the finished part has a hole.
The center lines show the center of the hole in the front view and top view.
The hidden lines show the edges of the hole in the front view.
The object lines show the shape of the finished part in the front view and top view.

EXAMPLE G



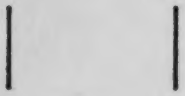
On this blueprint, the finished part has a curved end.
The center lines show the center of the curved end in the top view.

EXAMPLE H



On this blueprint, the finished part has 4 holes and a curved end.
The center lines show the centers of the 4 holes in the front view and top view.
The center lines show the center of the curved end in the top view.
The hidden lines show the edges of the 4 holes in the front view.

EXTENSION LINES



What do extension lines mean?

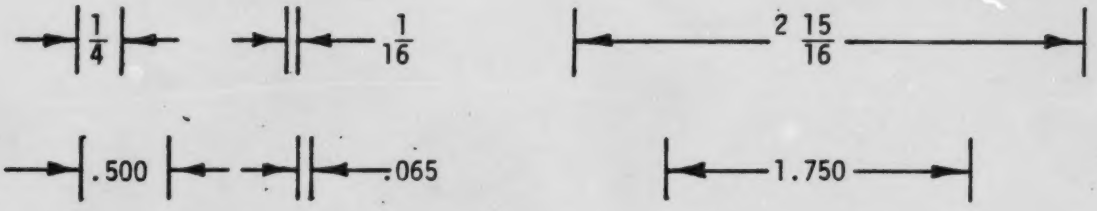
EXTENSION LINES and dimension lines show the dimensions of the finished part.

DIMENSION LINES

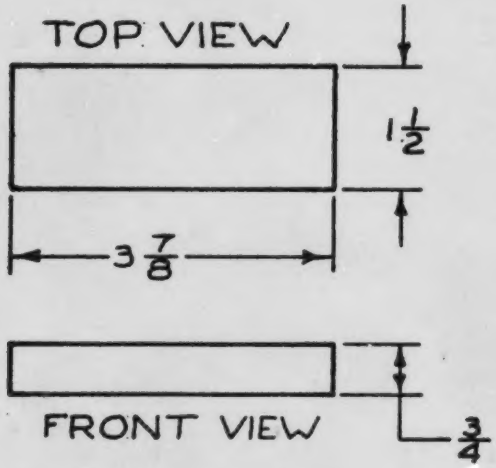
What do dimension lines mean?

DIMENSION LINES and extension lines show the dimensions of the finished part.
Dimension lines have arrows.

On blueprints, the drafter writes the exact dimensions inside the extension lines or outside the extension lines.



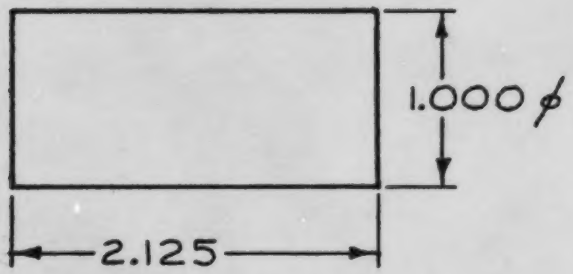
EXAMPLE I



On this blueprint, the extension lines and dimension lines show the length, width, and thickness of the finished part.

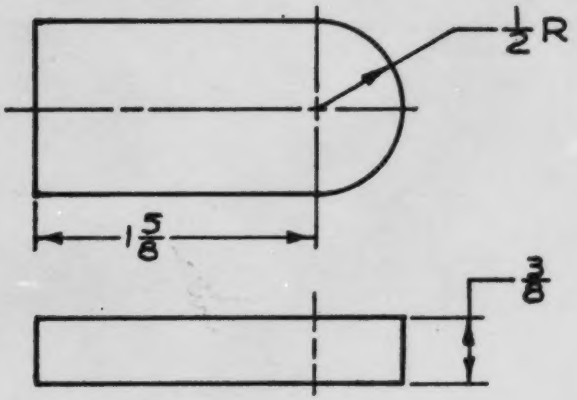
5C

EXAMPLE J



On this blueprint, the shape of this finished part is round (cylindrical). The extension lines and dimension lines show the diameter and length of the finished part.
Remember, ∅ is the symbol for diameter.

EXAMPLE K



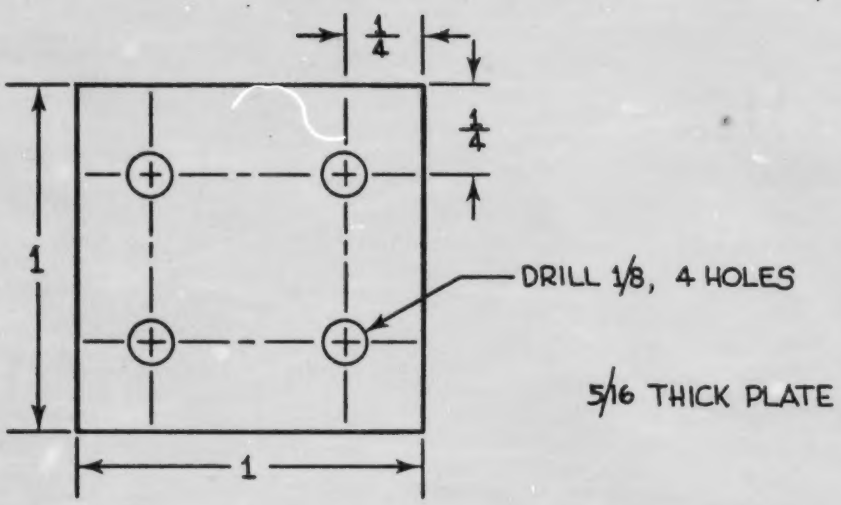
On this blueprint, the finished part has a curved end.
The radius of the curved end is $\frac{1}{2}$"
Remember, R is the abbreviation for radius.

LEADER LINES

What do leader lines mean?

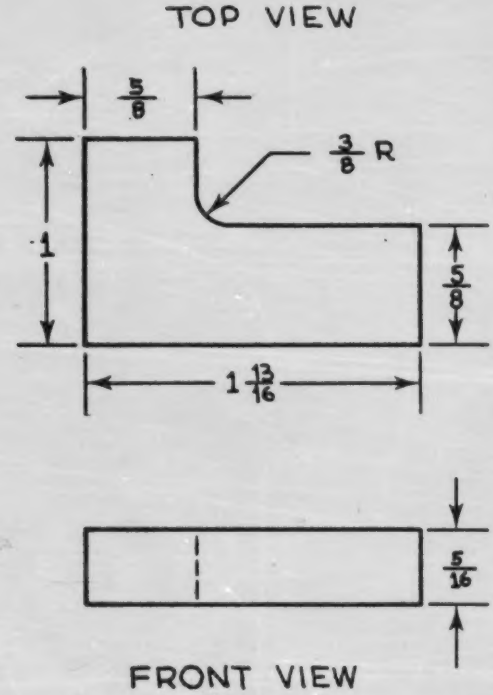
LEADER LINES give special technical information for a dimension on the finished part.
Leader lines have one arrow.

EXAMPLE L



On this blueprint, the finished part has 4 holes.
The leader line shows that each hole is $\frac{1}{8}$" in diameter.
The leader line tells the machinist to drill each hole.

EXAMPLE M



On this blueprint, the leader line shows a $\frac{3}{8}$" radius on the finished part.

SUMMARY

A blueprint is a picture of the finished part.

To give the exact shape of the finished part and the exact dimensions of the finished part, a blueprint uses different kinds of lines.

The 6 basic kinds of lines on a blueprint are:

1. OBJECT LINES
2. HIDDEN LINES
3. CENTER LINES
4. EXTENSION LINES
5. DIMENSION LINES
6. LEADER LINES

On a blueprint, each kind of line has a special meaning.

OBJECT LINES show the edges on the finished part.

HIDDEN LINES show edges or surfaces that the machinist cannot see in one view.

CENTER LINES show the center of the finished part, the center of a hole, or the center of a curved edge on the finished part.

EXTENSION LINES and dimension lines show the dimensions of the finished part.

DIMENSION LINES and extension lines show the dimensions of the finished part.

LEADER LINES give special information for a dimension on the finished part.

Machine Shop Fundamentals

5D

UNIT 5: Blueprint Reading

LESSON 5D: Tolerances

OBJECTIVES:

1. The student will write the correct definition of a blueprint.
2. The student will write the correct definition of tolerance.
3. The student will write the correct perfect dimension from a picture.
4. The student will write the correct meaning of $\pm$
5. The student will write the correct tolerance from a picture.
6. The student will write the correct upper limit of a dimension and lower limit of a dimension from a picture.

PROCEDURES:

1. Read the Objectives.
2. Read the Lesson.
3. Watch the teacher's Demonstration.
4. Do the Study Questions.
5. Do the Worksheets.
6. Do the Review Questions.
7. Do the Self-Test.

REFERENCES:

INTRODUCTION

A blueprint is a picture of a finished part.

A blueprint gives 2 main kinds of technical information:

1. The exact shape of the finished part
2. The exact dimensions of the finished part

A blueprint also gives other technical information to make the finished part.

On a blueprint, the views and lines work together to show the exact shape and exact dimensions of the finished part.

The machinist reads or interprets the views, lines, and other technical information on a blueprint to make the finished part.

DIMENSIONS ON A BLUEPRINT

An engineer designs the finished part.
He/she draws the exact shape of the finished part.
He/she figures out the perfect dimensions or exact dimensions of the finished part.

The engineer knows:

All parts need accurate dimensions.
But some parts need very accurate dimensions.
Accurate parts fit together with other parts.
Inaccurate parts do not fit together with other parts.
Inaccurate parts are called scrap.

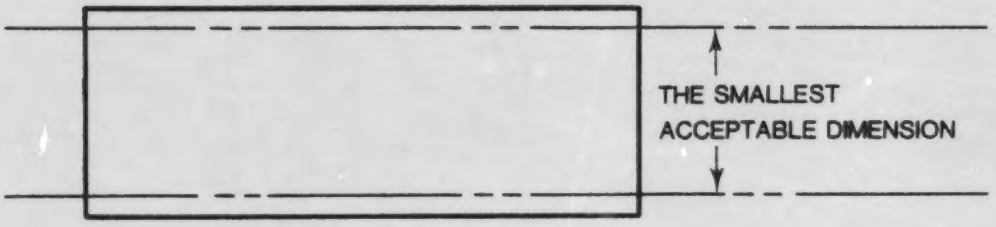
The engineer also knows:

Machine tools are not perfect.
Measurement tools are not perfect.
Machinists are not perfect.
Machinists cannot always make perfect dimensions on every finished part.
Sometimes the machinist makes a dimension on a part a little larger than the perfect dimension.
Sometimes the machinist makes a dimension on a part a little smaller than the perfect dimension.

First, the engineer figures out the perfect dimension or exact dimension for each dimension of the finished part.

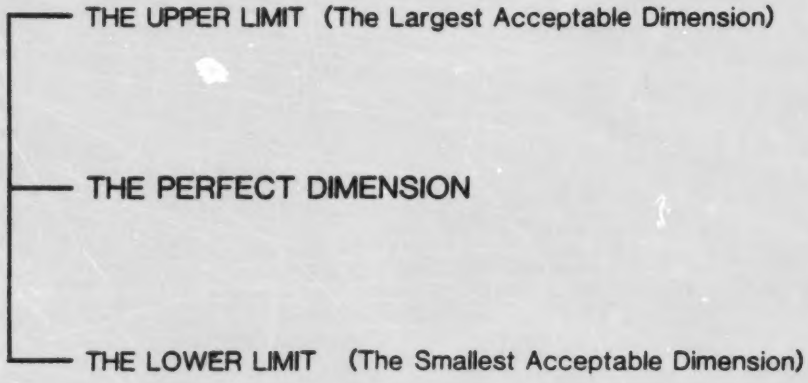
Then, he/she figures out the largest acceptable dimension for each dimension on the finished part.

Next, he/she figures out the smallest acceptable dimension for each dimension on the finished part.

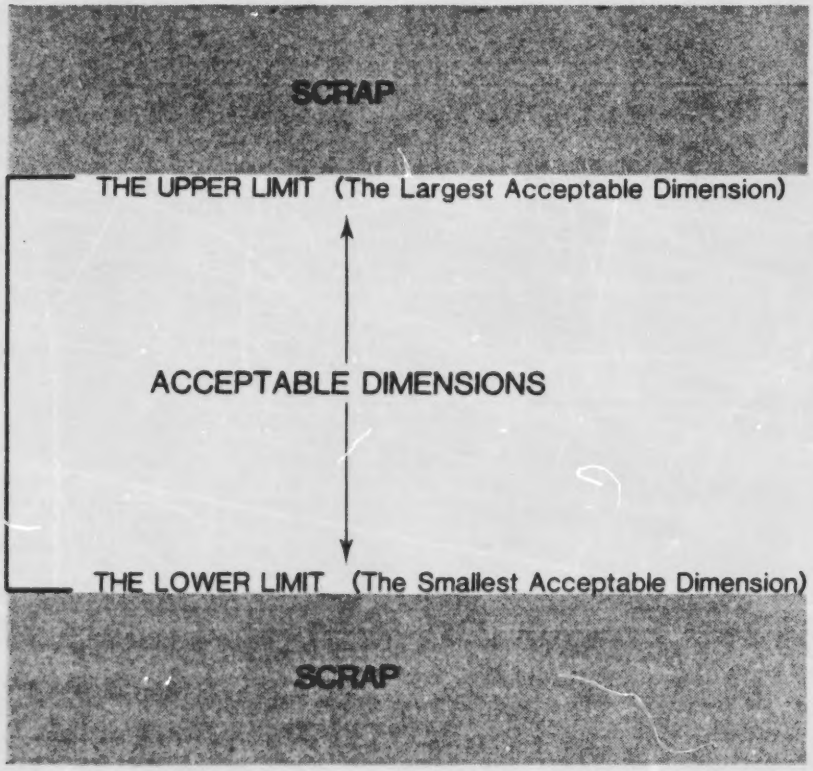


On blueprints, the engineer gives the largest acceptable dimension for each perfect dimension.
On blueprints, the largest acceptable dimesion (maximum acceptable dimension) is called the UPPER LIMIT.

On blueprints, the engineer gives the smallest acceptable dimension for each perfect dimension.
On blueprints, the smallest acceptable dimension (minimum acceptable dimension) is called the LOWER LIMIT.


THE UPPER LIMIT (The Largest Acceptable Dimension)
THE PERFECT DIMENSION
THE LOWER LIMIT (The Smallest Acceptable Dimension)

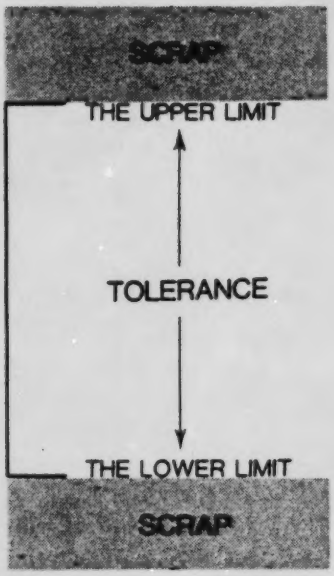
Every dimension between the upper limit and lower limit is an acceptable dimension.
Every dimension larger than the upper limit is not acceptable (scrap).
Every dimension smaller than the lower limit is not acceptable (scrap).



TOLERANCES ON A BLUEPRINT

What is tolerance?

TOLERANCE is the amount of acceptable size variation of a dimension on the finished part.



Every dimension between the upper limit and lower limit is acceptable.
We say acceptable dimensions are IN TOLERANCE.
An accurate part has acceptable dimensions.
All the dimensions of an accurate part are in tolerance.

Remember, a part has several dimensions.
Every dimension has an upper limit and a lower limit.

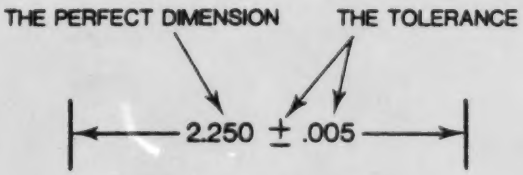
On blueprints, engineers and drafters use several ways to give the upper limit and lower limit of every dimension:

1. Perfect dimension with tolerances
2. Tolerances in the title block
3. Upper limits and lower limits

1. Perfect dimensions with tolerances

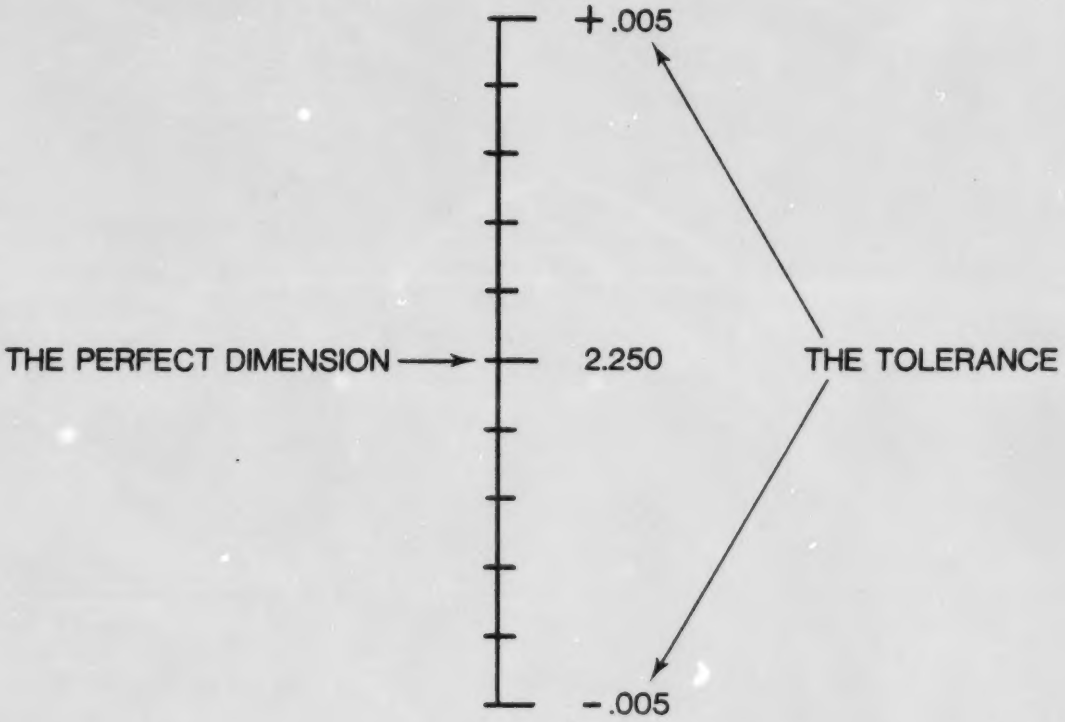
Sometimes, the engineer and drafter write the upper limit and the lower limit of a dimension as a PERFECT DIMENSION WITH A TOLERANCE.

EXAMPLE A



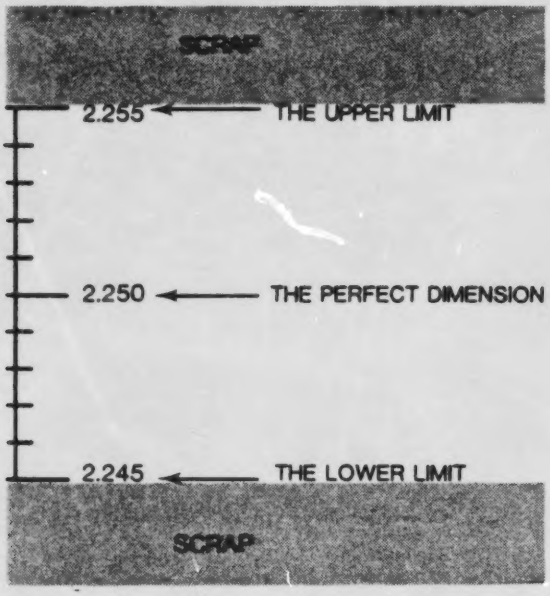
In EXAMPLE A, the perfect dimension is 2.250"
In EXAMPLE A, the tolerance is ± .005"

The symbol ± means PLUS (+) OR MINUS (-).
Plus means larger, or more.
Minus means smaller, or less.



The machinist uses the perfect dimension and the tolerance to figure out the upper limit and lower limit.

2.250	The Perfect Dimension	2.250	The Perfect Dimension
+ .005	+ Tolerance	- .005	- Tolerance
2.255	The Upper Limit	2.245	The Lower Limit



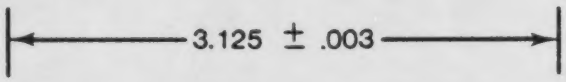
In EXAMPLE A, 2.255" is the upper limit or largest acceptable size.
In EXAMPLE A, 2.245" is the lower limit or smallest acceptable size.

Every dimension between 2.255" and 2.245" is in tolerance (acceptable).
For example, 2.254" is in tolerance.
For example, 2.248" is in tolerance.

Every dimension larger than 2.255" (the upper limit) is not acceptable.
For example, 2.256" is not acceptable.
For example, 2.260" is not acceptable.

Every dimension smaller than 2.245" (the lower limit) is not acceptable.
For example, 2.244" is not acceptable.
For example, 2.230" is not acceptable.

EXAMPLE B

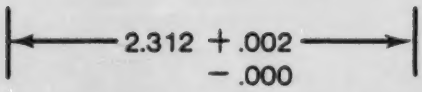


In EXAMPLE B, the perfect dimension is 3.125"
In EXAMPLE B, the tolerance is ± .003"

3.125		3.125	
+ .003		- .003	
3.128	The Upper Limit	3.122	The Lower Limit

In EXAMPLE B, 3.128" is the upper limit.
In EXAMPLE B, 3.122" is the lower limit.

EXAMPLE C

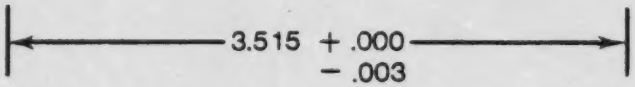


In EXAMPLE C, the perfect dimension is 2.312"
In EXAMPLE C, the tolerance is + .002" or - .000"

2.312		2.312	
+ .002		- .000	
2.314	The Upper Limit	2.312	The Lower Limit

In EXAMPLE C, the upper limit is 2.314"
In EXAMPLE C, the lower limit is 2.312"

EXAMPLE D



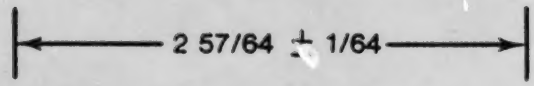
In EXAMPLE D, the perfect dimension is 3.515"
In EXAMPLE D, the tolerance is + .000 or - .003"

3.515		3.515	
+ .000		- .003	
3.515	The Upper Limit	3.512	The Lower Limit

In EXAMPLE D, the upper limit is 3.515"
In EXAMPLE D, the lower limit is 3.512"

Sometimes the tolerance is + .000 or - .000
If the tolerance is + .000 then the perfect dimension and the upper limit are the same.
If the tolerance is - .000 then the perfect dimension and the lower limit are the same.

EXAMPLE E



In EXAMPLE E, the perfect dimension is $2\ \frac{57}{64}$"

In EXAMPLE E, the tolerance is $\pm\ \frac{1}{64}$"

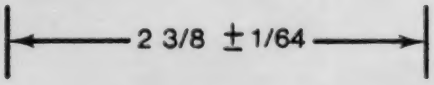
$$\begin{array}{r} 2\ \frac{57}{64} \\ +\ \frac{1}{64} \\ \hline 2\ \frac{58}{64} = 2\ \frac{29}{32} \end{array}$$ The Upper Limit

$$\begin{array}{r} 2\ \frac{57}{64} \\ -\ \frac{1}{64} \\ \hline 2\ \frac{56}{64} = 2\ \frac{7}{8} \end{array}$$ The Lower Limit

In EXAMPLE E, the upper limit is $2\ \frac{29}{32}$"

In EXAMPLE E, the lower limit is $2\ \frac{7}{8}$"

EXAMPLE F



In EXAMPLE F, the perfect dimension $2\ \frac{3}{8}$"

In EXAMPLE F, the tolerance is $\pm\ \frac{1}{64}$"

$$\begin{array}{r} 2\ \frac{3}{8} = 2\ \frac{24}{64} \\ +\ \frac{1}{64} = \frac{1}{64} \\ \hline 2\ \frac{25}{64} \end{array}$$ The Upper Limit

$$\begin{array}{r} 2\ \frac{3}{8} = 2\ \frac{24}{64} \\ -\ \frac{1}{64} = \frac{1}{64} \\ \hline 2\ \frac{23}{64} \end{array}$$ The Lower Limit

In EXAMPLE F, the upper limit is $2\ \frac{25}{64}$"

In EXAMPLE F, the lower limit is $2\ \frac{23}{64}$"

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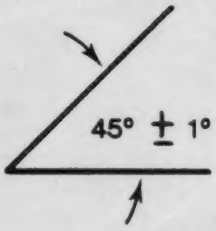
EXAMPLE G



In EXAMPLE G, the perfect dimension is 45 degrees.
In EXAMPLE G, the tolerance is ± 1 degree.

$$\begin{array}{r} 45^\circ \\ +\ 1^\circ \\ \hline 46^\circ \end{array}$$ The Upper Limit

$$\begin{array}{r} 45^\circ \\ -\ 1^\circ \\ \hline 44^\circ \end{array}$$ The Lower Limit

In EXAMPLE G, the upper limit is 46 degrees.
In EXAMPLE G, the lower limit is 44 degrees.

2. Tolerances in the title block

The engineer and drafter do not always write tolerances with the perfect dimension.
Many times, they write the TOLERANCES IN THE TITLE BLOCK

THE TITLE BLOCK

MATERIAL Cold Rolled Steel			Qty Req'd 1	Casting Specialties Corp. Cedarburg, Wis.	
TOLERANCES UNLESS OTHERWISE SPECIFIED:				HANDLE	
Fractions ±1/64	Decimals ±.005	Angles ±1°		PART N° 4-104	30M3276

If a dimension on the blueprint does not have a specific tolerance on the dimension line, the machinist looks for the tolerance for that dimension in the title block.
He/she looks for a box with tolerances in the title block.
Many times, this box says TOLERANCES UNLESS OTHERWISE SPECIFIED.

The machinist uses the perfect dimension and the tolerance in the title block to figure out the upper limit and lower limit.

Many companies have standard tolerances.

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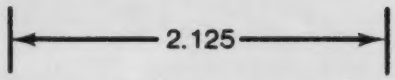
EXAMPLE H



TOLERANCES UNLESS OTHERWISE SPECIFIED:		
Fractions	Decimals	Angles
±1/64	±.005	±1°

In EXAMPLE H, the dimension does not have a specific tolerance.
Then, the machinist must look at the tolerances in the title block.
2.125 is a decimal.
The machinist reads the tolerance for this decimal in the title block.

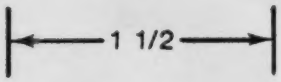
He/she reads that the tolerance for decimals is ± .005

$$\begin{array}{r} 2.125 \\ +\ .005 \\ \hline 2.130 \end{array}$$ The Upper Limit

$$\begin{array}{r} 2.125 \\ -\ .005 \\ \hline 2.120 \end{array}$$ The Lower Limit

In EXAMPLE H, the upper limit is 2.130"
In EXAMPLE H, the lower limit is 2.120"

EXAMPLE I



TOLERANCES UNLESS OTHERWISE SPECIFIED:		
Fractions	Decimals	Angles
±1/64	±.005	±1°

In EXAMPLE I, the dimension does not have a specific tolerance.
Then, the machinist reads the tolerance in the title block.
$1\frac{1}{2}$ is a fraction.
The machinist reads the tolerance for this fraction in the title block.
He/she reads that the tolerance for fractions is $\pm \frac{1}{64}$

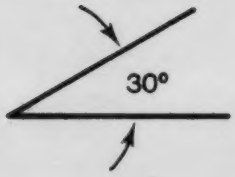
$$\begin{array}{r} 1\frac{1}{2} = 1\frac{32}{64} \\ +\ \frac{1}{64} = \frac{1}{64} \\ \hline 1\frac{33}{64} \end{array}$$ The Upper Limit

$$\begin{array}{r} 1\frac{1}{2} = 1\frac{32}{64} \\ -\ \frac{1}{64} = \frac{1}{64} \\ \hline 1\frac{31}{32} \end{array}$$ The Lower Limit

In EXAMPLE I, the upper limit is $1\frac{33}{64}$"

In EXAMPLE I, the lower limit is $1\frac{31}{64}$"

EXAMPLE J



TOLERANCES UNLESS OTHERWISE SPECIFIED:		
Fractions	Decimals	Angles
±1/64	±.005	±1°

In EXAMPLE J, the dimension does not have a specific tolerance.
Then, the machinist reads the tolerance in the title block.
30° is an angle.
The machinist reads the tolerance for this angle in the title block.
He/she reads that the tolerance for angles is ± 1°

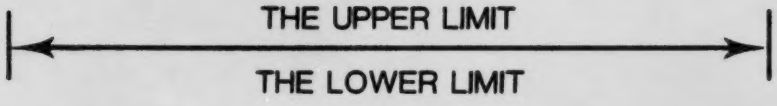
$$\begin{array}{r} 30° \\ +\ 1° \\ \hline 31° \end{array}$$ The Upper Limit

$$\begin{array}{r} 30° \\ -\ 1° \\ \hline 29° \end{array}$$ The Lower Limit

In EXAMPLE J, the upper limit is 31°
In EXAMPLE J, the lower limit is 29°

3. Upper limits and lower limits

Sometimes, the drafter does not write the perfect dimension with the tolerance on the dimension line.
He/she does not write the perfect dimension.
He/she does not write the tolerance.
Instead, the drafter writes THE UPPER LIMIT ABOVE THE DIMENSION LINE and THE LOWER LIMIT BELOW THE DIMENSION LINE.
Then, the machinist does not have to figure out the upper limit and lower limit of the dimension.



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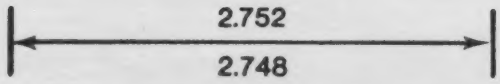
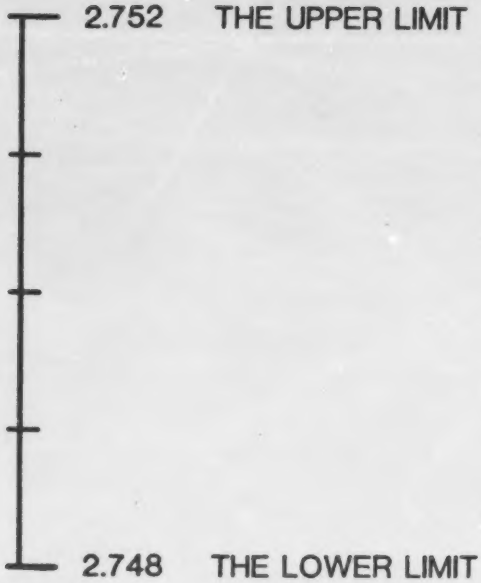
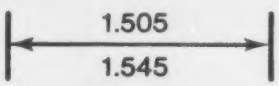
EXAMPLE K





In EXAMPLE K, the upper limit is 2.752"
In EXAMPLE K, the lower limit is 2.748"

EXAMPLE L



In EXAMPLE L, the upper limit is 1.505"
In EXAMPLE L, the lower limit is 1.545"

The drafter can write the upper limit and the lower limit on the dimension line for decimal numbers.
He/she does not write the upper limit and the lower limit on the dimension line for fractional numbers.
He/she does not write the upper limit and lower limit on the dimension line for angles.

SUMMARY

What is tolerance?

TOLERANCE is the amount of acceptable size variation of a dimension on a part.

The symbol $\pm$ means PLUS (+) OR MINUS (-).

On blueprints, engineers and drafters use several ways to give the upper limit and lower limit of every dimension:

1. Perfect dimension with tolerances
2. Tolerances in the title block
3. Upper limits and lower limits

Machine Shop Fundamentals

5E

UNIT 5: Blueprint Reading

LESSON 5E: Title Blocks

OBJECTIVES:

1. The student will write the correct definition of a blueprint.
2. The student will write the names of the 2 main parts of a blueprint.
3. The student will choose this technical information from a title block on a blueprint:
   a. The name and address of the company
   b. The name of the finished part
   c. The part number of the finished part
   d. The number of the blueprint
   e. The tolerances
   f. The number or quantity of the finished part required
   g. The material or kind of metal of the finished part
   h. The scale of the finished part on the blueprint

PROCEDURES:

1. Read the Objectives.
2. Read the Lesson.
3. Watch the teacher's Demonstration.
4. Do the Study Questions.
5. Do the Worksheets.
6. Do the Review Questions.
7. Do the Self-Test.

REFERENCES:

INTRODUCTION

A blueprint is a picture of a finished part.

A blueprint gives 2 main kinds of technical information:

1. The exact shape of the finished part
2. The exact dimensions of the finished part

A blueprint also gives other technical information to make the finished part.

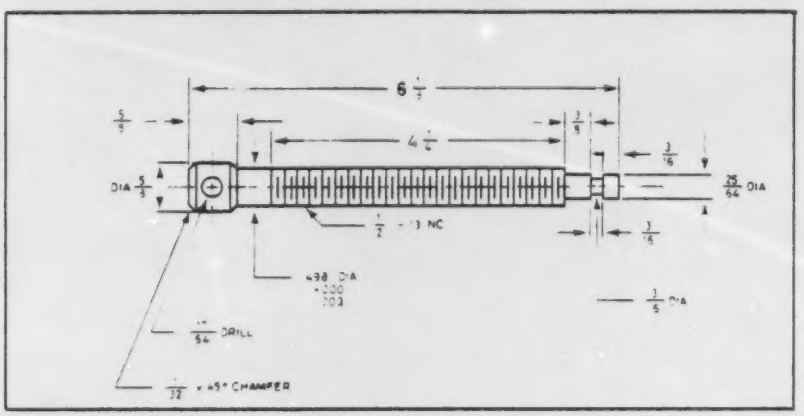
On a blueprint, the views, lines, and tolerances work together to show the exact dimensions and exact shape of the finished part.

The machinist reads or interprets the views, lines, tolerances, and other technical information on a blueprint to make the finished part.

TITLE BLOCKS

All blueprints have 2 main parts (general meaning):

1. The Body (Views, Dimensions)
2. The Title Block



The Body

The Title Block

On a blueprint, the TITLE BLOCK has technical information necessary to make the finished part.
Some title blocks have a little technical information.

Some title blocks have a lot of technical information.
Different companies have different kinds of title blocks on their blueprints.
But, a blueprint always gives all the technical information to make the finished part.

Some of the most important kinds of technical information in a title block are:

1. THE NAME AND ADDRESS OF THE COMPANY
2. THE NAME OF THE FINISHED PART
3. THE NUMBER OF THE BLUEPRINT
4. THE PART NUMBER OF THE FINISHED PART
5. THE TOLERANCES
6. THE NUMBER OR QUANTITY OF FINISHED PARTS REQUIRED
7. THE MATERIAL OR KIND OF METAL OF THE FINISHED PART
8. THE SCALE OF THE FINISHED PART ON THE BLUEPRINT

<table>
<tr><td>MATERIAL
Cold Rolled Steel</td><td>Qty Req'd
1</td><td colspan="2">Casting Specialties Corp.
Cedarburg, Wis.</td></tr>
<tr><td colspan="2" rowspan="2">TOLERANCES UNLESS OTHERWISE SPECIFIED:
Fractions ± 1/64 Decimals ± .005 Angles ± 1°</td><td colspan="2">LEADSCREW</td></tr>
<tr><td>PART N°
4-106</td><td>30M3274</td></tr>
</table>

1. In this title block, the name and address of the company is Casting Specialties Corp., Cedarburg, Wis.

2. In this title block, the name of the finished part is the leadscrew.

3. In this title block, the number of the blueprint is 30M3274.

4. In this title block, the part number is 4-106.
   Many blueprints use the abbreviation NO. or the symbol # for number.

5. Some dimensions on this blueprint have tolerances on the dimension line.
   In this title block, the tolerances for dimensions without tolerances on the dimension line are:

   FRACTIONS $\pm \frac{1}{64}$ DECIMALS $\pm$ .005 ANGLES $\pm$ 1°

6. In this title block, the number or quantity of finished parts required is 1.
   Different blueprints use different abbreviations for the number of finished parts required.

   Qty Req'd = Quantity Required Qty = Quantity Req'd = Required
   No. Req = Number Required Req = Required

7. In this title block, the material or kind of metal of the finished part is cold rolled steel.
   Sometimes, blueprints use the abbreviation MAT'L for material.

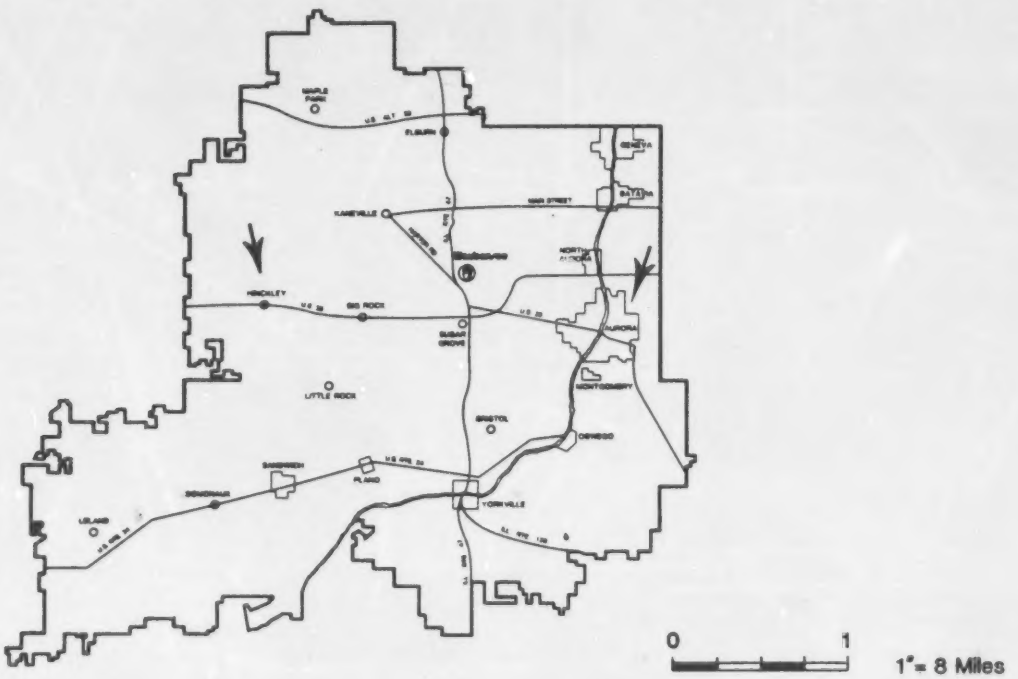
	DATE	BY	MAT'L	UNLESS OTHERWISE SPECIFIED TOLERANCES ON DIMENSIONS ARE:	THE COOTS CORP. Chicago, Ill.	SLIDE PLATE	
DRAWN	6/1/81	M. Johnson	Aluminum	DECIMAL DIMENSIONS ± .003			
CHECKED	6/3/81	J. Diaz	QTY 50	FRACTIONAL DIMENSIONS ± 1/64		PART # 351-T-283	
APPROVED	6/9/81	N. Paul		ANGULAR DIMENSIONS ± 1/2°		SCALE 1/2"=1"	T327-5

1. In this title block, the name of the finished part is the slide plate.

2. In this title block, the part number is 351-T-283

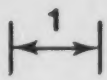
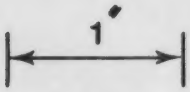
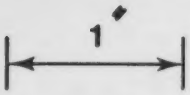
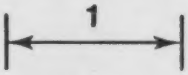
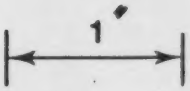
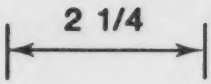
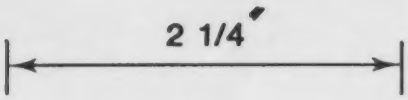
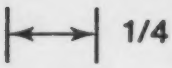
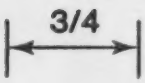
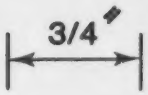
3. In this title block, the number of the blueprint is T327-5

4. In this title block, the SCALE of the finished part on the blueprint is $\frac{1}{2}$" = 1"
   When the scale is $\frac{1}{2}$" = 1" the drafter draws $\frac{1}{2}$" on the blueprint for each 1" on the finished part.
   Many times, a finished part is too big or too small for the drafter to draw the real or full size of the finished part on the blueprint.
   The drafter draws the finished part TO SCALE.
   Maps and blueprints have scale.



On this map, 1" equals 8 miles.
The real distance between Aurora and Hinckley is 16 miles.
On this map, the scale is 1" = 8 miles.

(5E)

Title Block	The Dimension on the Blueprint	The Real Size on the Finished Part
Scale $\frac{1"}{2}$ = 1"		
Scale 2" = 1"		
Scale 1" = 1" or FULL SIZE		
Scale $\frac{1"}{2}$ = 1"		
Scale 2" = 1"		
Scale 1" or FULL SIZE		

5. In this title block, the name of the company is Coots Corp.

6. Some dimensions on this blueprint have tolerances on the dimension line. In this title block, the tolerances for dimensions without tolerances on the dimension line are:

   FRACTIONS $\pm \frac{1}{64}$ DECIMALS $\pm$ .003 ANGLES $\pm 1°$

7. This title block gives the name of the drafter and the date that he/she drew the blueprint.

8. This title block gives the name of the inspector and the date that he/she checked the blueprint.

9. This title block gives the name of the engineer or supervisor and the date that he/she approved the blueprint.

10. In this title block, the material or kind of metal of the finished part is aluminum.
Sometimes blueprints use the abbreviation MAT'L for material.

11. In this title block, the number or quantity of finished parts required is 50.

A machinist carefully reads all the technical information on a blueprint.

If the machinist does not understand something on a blueprint, he/she asks the teacher or foreman.

SUMMARY

A blueprint is a picture of a finished part.

A blueprint gives 2 main kinds of technical information:

1. The exact shape of the finished part
2. The exact dimensions of the finished part

A blueprint also gives other technical information to make the finished part.

On a blueprint, the views, lines, and tolerances work together to show the exact shape and exact dimensions of the finished part.

The machinist reads or interprets the views, lines, tolerances, and other technical information on a blueprint to make the finished part.

All blueprints have 2 main parts:

1. The Body (Views, Dimensions)
2. The Title Block

On a blueprint, the title block has technical information to make finished parts.

Different companies have different kinds of title blocks on their blueprints.

A blueprint always gives all the technical information to make the finished part.

A machinist carefully reads all the technical information on a blueprint.

If the machinist does not understand something on a blueprint, he/she asks the teacher or foreman.

Machine Shop Fundamentals

6A

UNIT 6: Layout

LESSON 6A: Introduction to Layout

OBJECTIVES:
1. The student will write the correct definition of layout.
2. The student will write the names of the 2 kinds of layout.
3. The student will write the 3 steps to lay out a part.

PROCEDURES:
1. Read the Objectives.
2. Read the Lesson.
3. Watch the teacher's Demonstration.
4. Do the Study Questions.
5. Do the Review Questions.
6. Do the Self-Test.

REFERENCES:

INTRODUCTION

A skilled machinist uses machine tools to make a finished part.

A machinist must make accurate parts.
Accurate parts fit together with other parts.
Inaccurate parts do not fit together with other parts.

A machinist must make accurate measurements to make accurate layouts.
Accurate layouts and accurate machine operations make accurate parts.

To make a finished part, the machinist usually follows these steps:

STEP 1. The machinist reads the blueprint of the finished part.

STEP 2. The machinist lays out the part.

STEP 3. The machinist sets up the machine tool.

STEP 4. The machinist runs the machine tool.

STEP 5. The machinist measures the part to check the dimensions of the part.
He/she compares the dimensions of the part to the blueprint specifications.

LAYOUT

What is layout?

Marking exact dimensions on a part is called LAYOUT.

The machinist marks an exact dimension on a part with a line.

This line is called a LAYOUT LINE.

There are 2 main kinds of layout:

1. Semiprecision Layout (Accurate to within $\pm \frac{1}{64}$")

2. Precision Layout (Accurate to within $\pm$ .001")

For semiprecision layout, the machinist uses semiprecision measurement tools and semiprecision layout tools.

For precision layout, the machinist uses precision measurement tools and precision layout tools.

LAYING OUT A PART

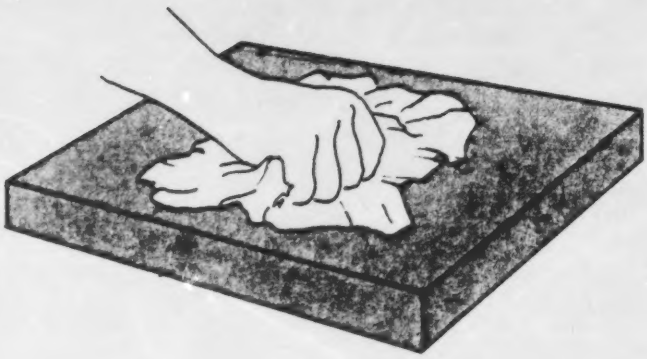
To lay out a part, a machinist follows these steps:

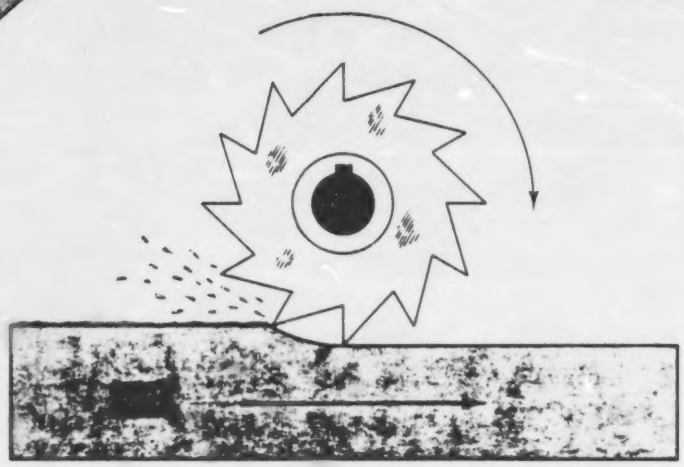
STEP 1. Clean the surfaces of the part.

STEP 2. Brush or spray layout dye on the part.

STEP 3. Mark the exact dimensions on the part with layout lines.

STEP 1. Clean the surfaces on the part

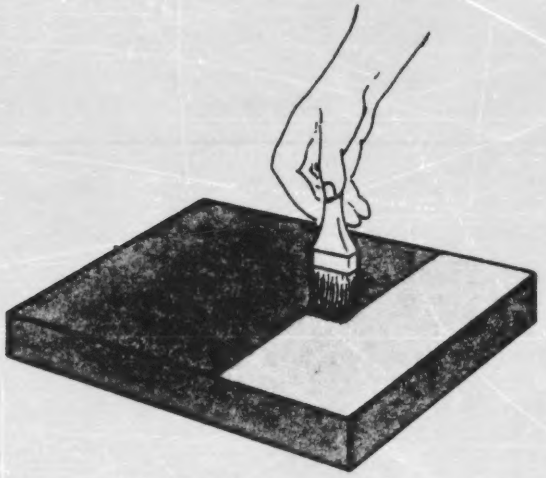




For parts with smooth surfaces, the machinist must wipe off dirt, oil, grease, or rust.

For parts with rough surfaces, such as castings, the machinist must use a machine tool to clean up the rough surfaces on the part.
Here, clean up means to make the rough surfaces on a part smooth with a machine tool.

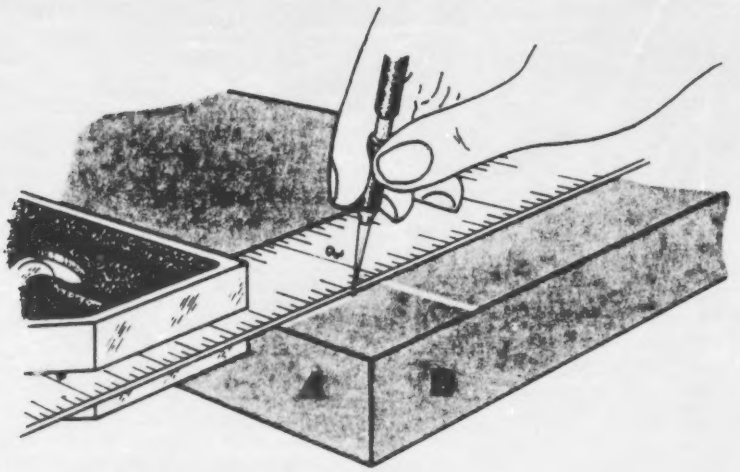
STEP 2. Brush or spray layout dye on the part.



LAYOUT BLUE is like paint.

There are many different kinds of layout blue for different kinds of metal.
Many times layout blue is called LAYOUT DYE.
The machinist brushes or sprays layout dye on the part.

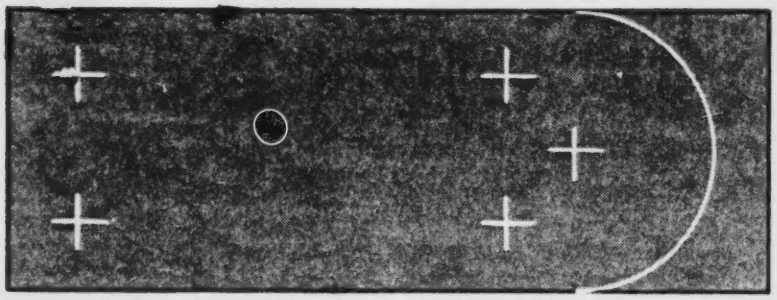
STEP 3. Mark the exact dimensions on the part with layout lines.

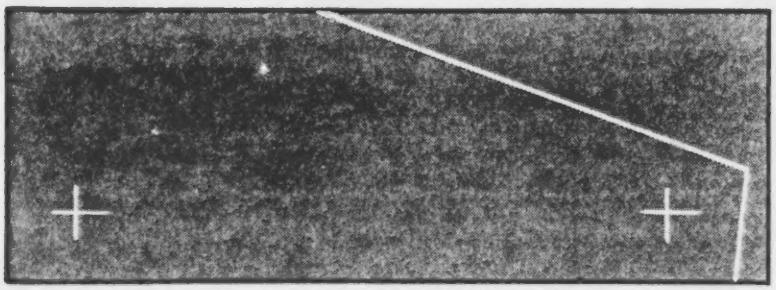


The machinist reads the blueprint to find the exact dimensions of the finished part.
He/she marks the exact dimensions on the part with layout lines.
He/she uses measurement tools and layout tools to find the exact dimensions and to mark the layout lines on the part.

He/she uses semiprecision measurement tools and semiprecision layout tools for semiprecision accuracy and semiprecision layout.
He/she uses precision measurement tools and precision layout tools for precision accuracy and precision layout.

A machinist laid out these two parts.





Machine Shop Fundamentals

6B

UNIT 6: Layout

LESSON 6B: Semiprecision Layout

OBJECTIVES:

1. The student will write the correct definition of layout.
2. The student will match the name of a semiprecision layout tool to a picture of that layout tool.
3. The student will choose the correct layout tool from a description of that layout tool.

PROCEDURES:

1. Read the Objectives.
2. Read the Lesson.
3. Watch the teacher's Demonstration.
4. Do the Study Questions.
5. Do the Worksheets.
6. Do the Review Questions.
7. Do the Self-Test.

REFERENCES:

INTRODUCTION

What is a layout?

Marking exact dimensions on a part is called layout.

The machinist marks an exact dimension on a part with a line. This line is called a layout line.

For semiprecision layout, the machinist uses semiprecision measurement tools and semiprecision layout tools.

For precision layout, the machinist uses precision measurement tools and precision layout tools.

To lay out a part, a machinist follows these steps:

STEP 1. Clean the surfaces on the part.

STEP 2. Brush or spray layout dye on the part.

STEP 3. Mark the exact dimensions on the part with layout lines.

SEMIPRECISION LAYOUT

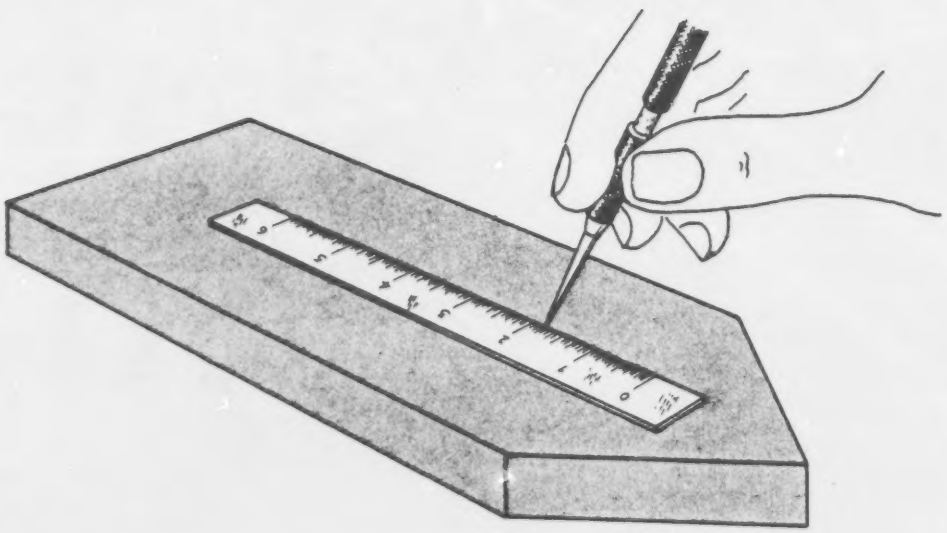
The machinist reads the blueprint to find the exact dimensions of the finished part.

For most layout work, the machinist uses a SURFACE PLATE.

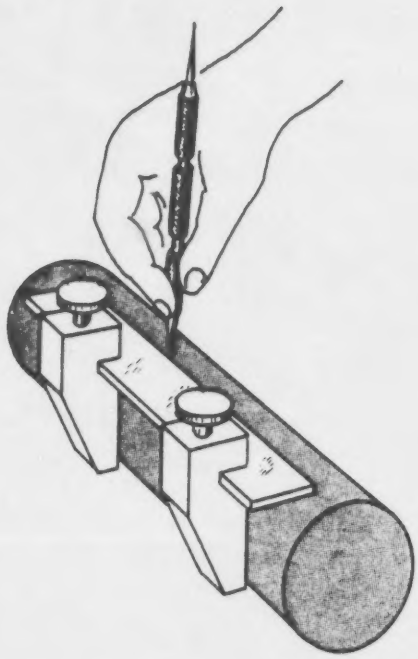
A surface plate is very flat and smooth. Most surface plates are flat to ± .00001"

The machinist marks an exact dimension on a part with a line.
Many times, the machinist uses a SCRIBER to mark an exact dimension on a part.
A scriber marks a line on the part.
This line is called a layout line.
A scriber has a very sharp point.

Sometimes the machinist uses a 6" rule and a scriber to lay out a part.



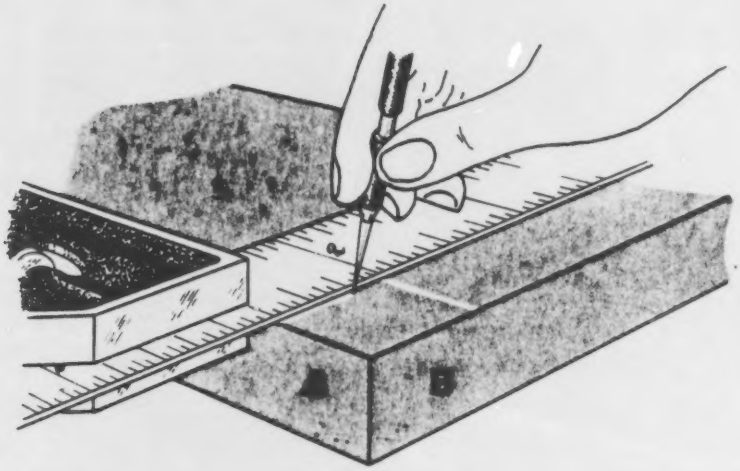
For round parts, the machinist sometimes uses a 6" rule, a scriber, and KEYSEAT CLAMPS.



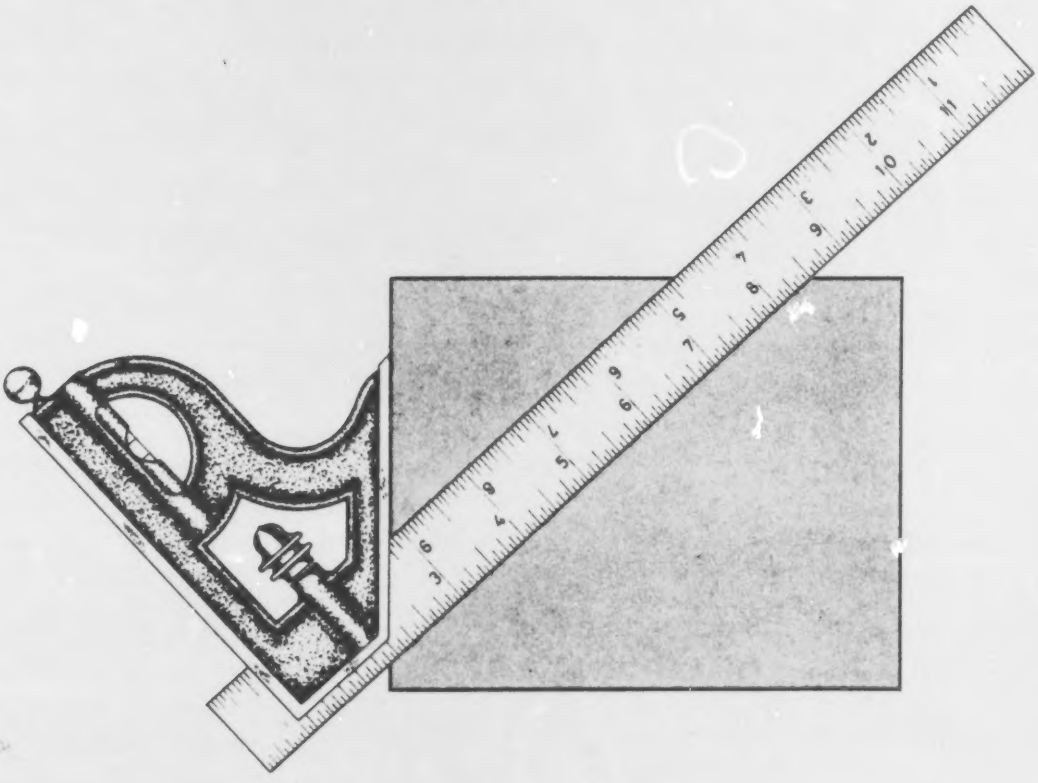
The machinist can also use a combination square to lay out parts.

A combination square has a 90° corner and a 45° corner.

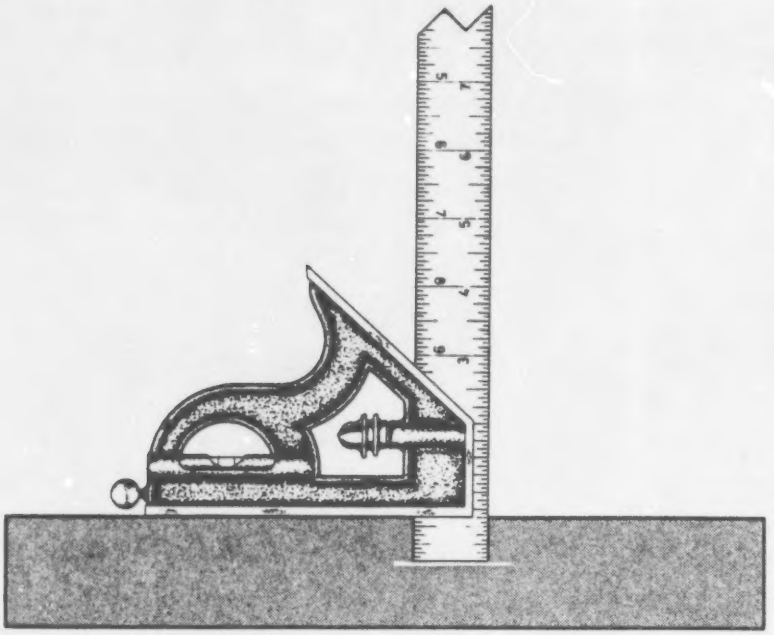
The machinist lays out parts with the combination square.



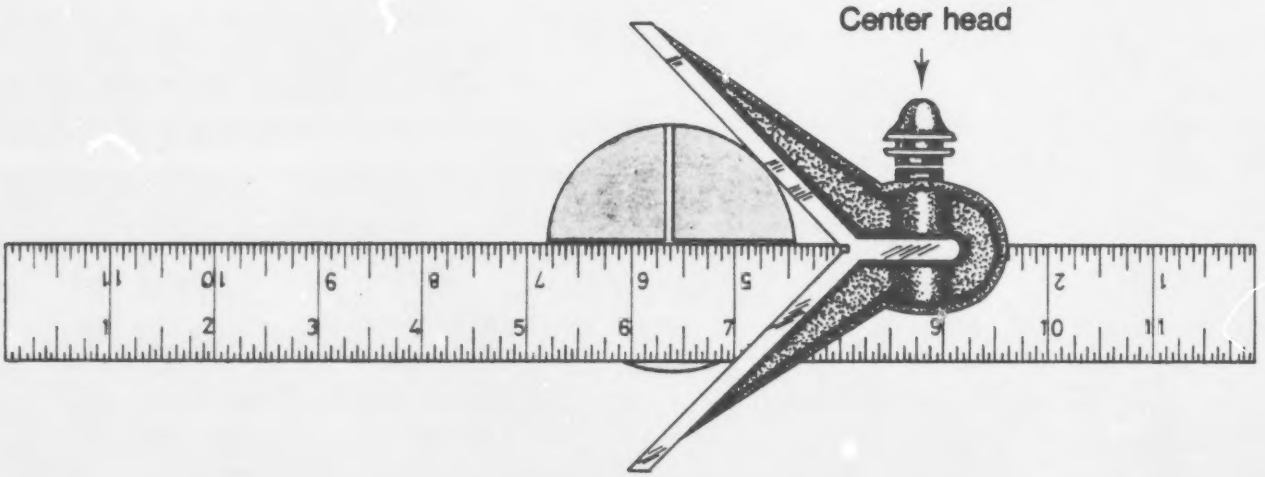
The machinist lays out 45° angles on parts with the combination square.



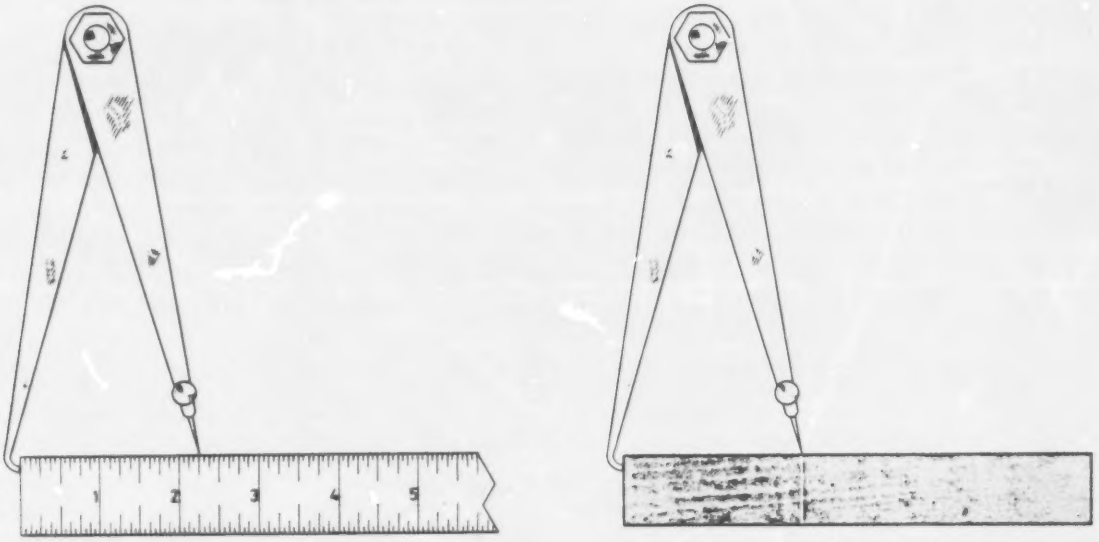
The machinist lays out the depth of a slot with the combination square.



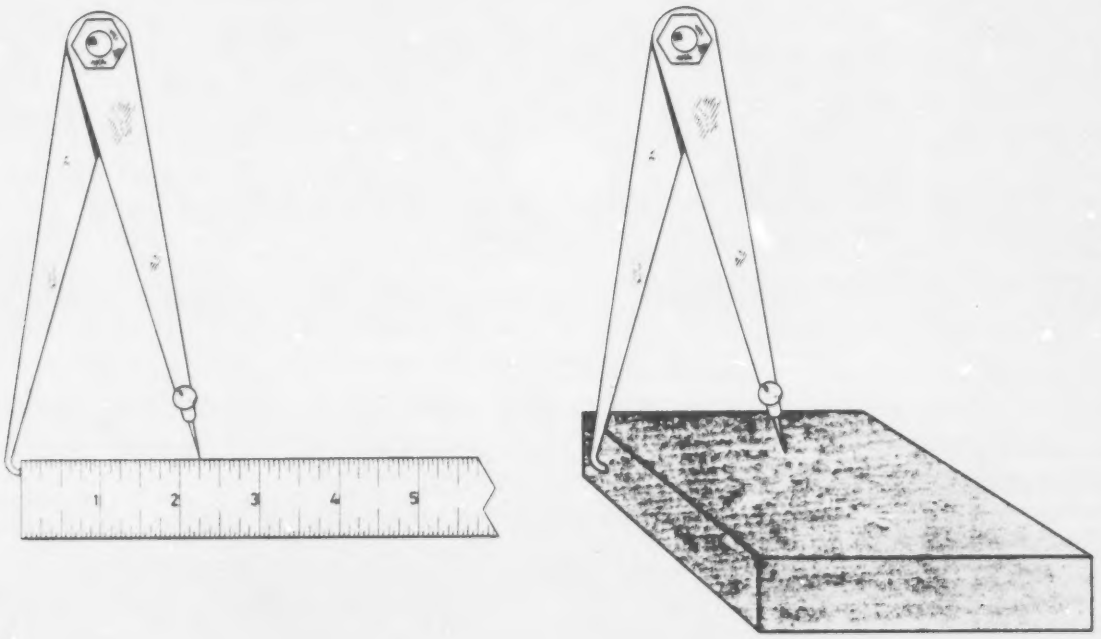
The machinist lays out the center of a round (cylindrical) part with a CENTER HEAD.



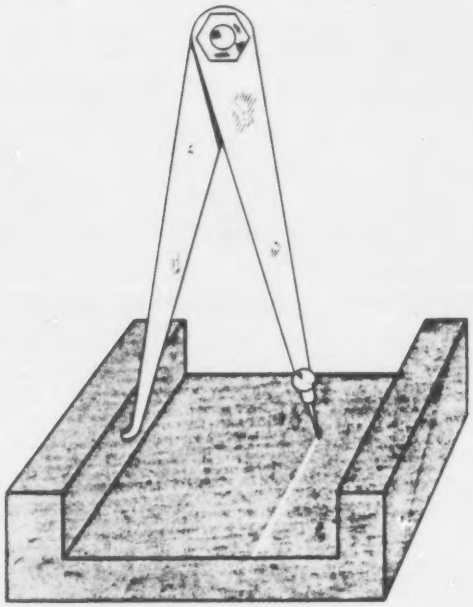
The machinist uses a HERMAPHRODITE CALIPER to lay out parts.
The machinist lays out an exact dimension on a round part with a hermaphrodite caliper and a 12" rule.



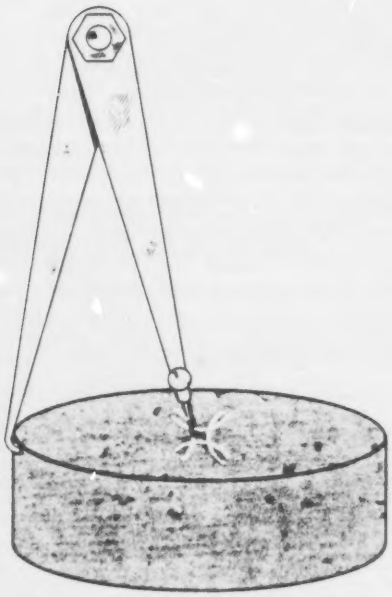
The machinist lays out an exact dimension on a part with a hermaphrodite caliper and a 6" rule.



The machinist lays out an exact dimension on a part with a hermaphrodite caliper and a 6" rule.



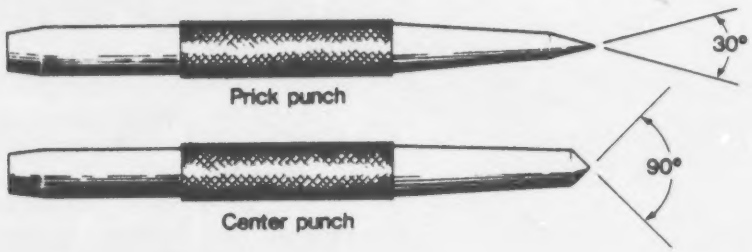
The machinist lays out the center of a round part with a hermaphrodite caliper and a 6" rule.



Sometimes, the machinist uses a PUNCH and a hammer to lay out exact dimensions on a part.

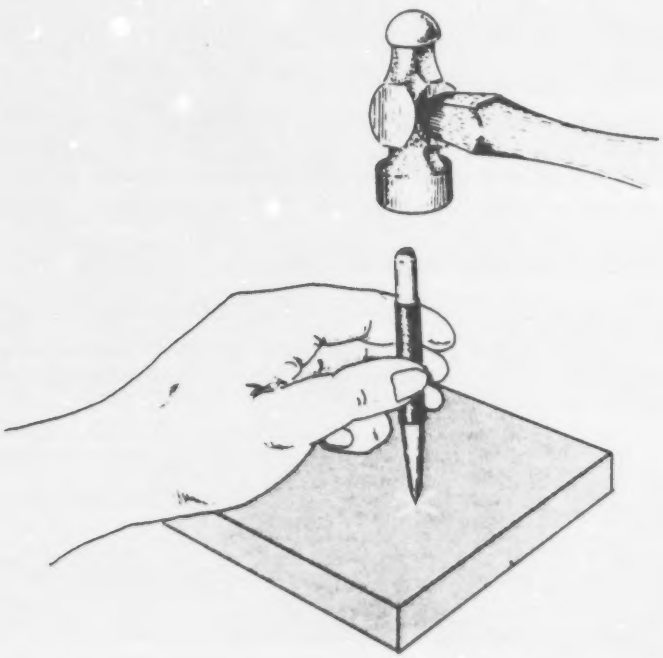
For layout, there are 2 kinds of punches:

1. THE PRICK PUNCH
2. THE CENTER PUNCH

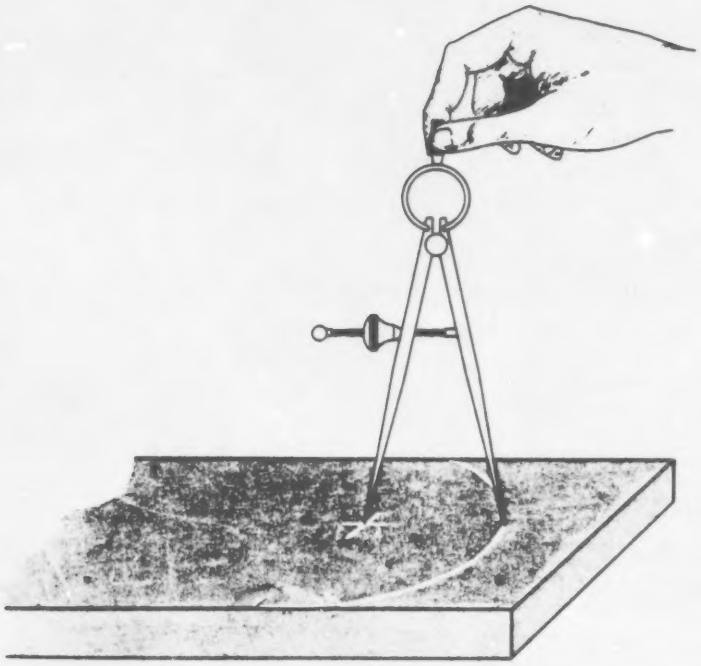


The prick punch has a 30° point.
The center punch has a 90° point.

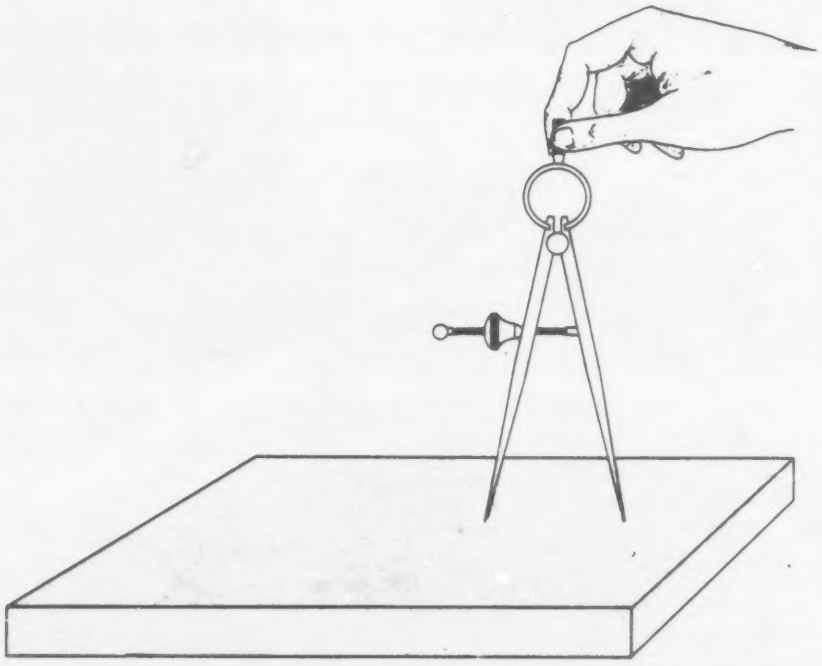
The machinist uses a prick punch and a hammer to lay out the center of a radius or the center of a circle.



First, the machinist lays out the center of a radius or the center of a circle. Then, he/she marks the center with a prick punch and a hammer.

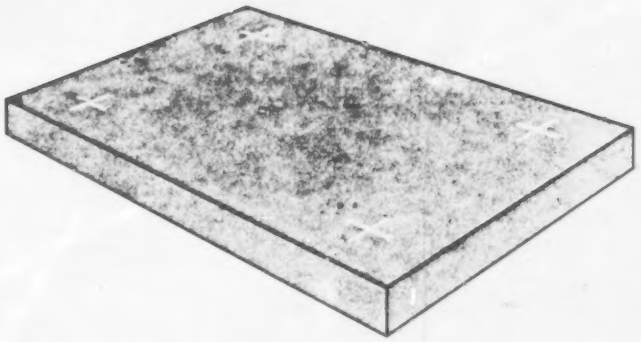


Last, the machinist uses DIVIDERS to lay out the radius on the part.

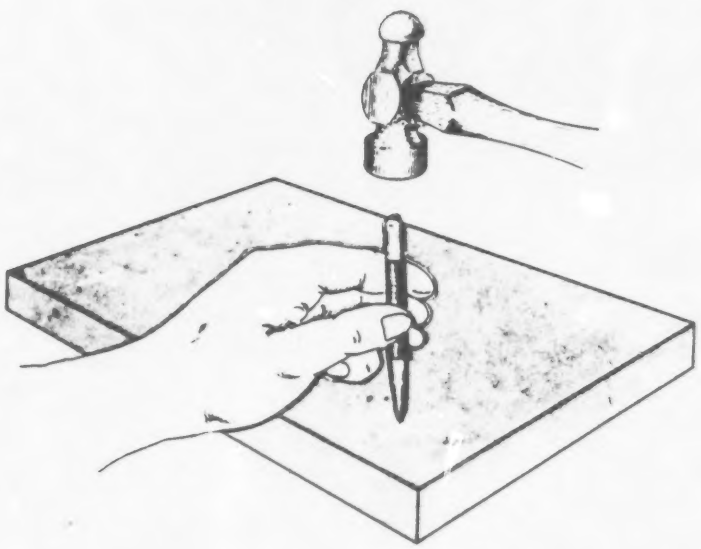


The machinist also uses dividers to lay out circles on parts.

To lay out a hole, first the machinist lays out the center of the hole.

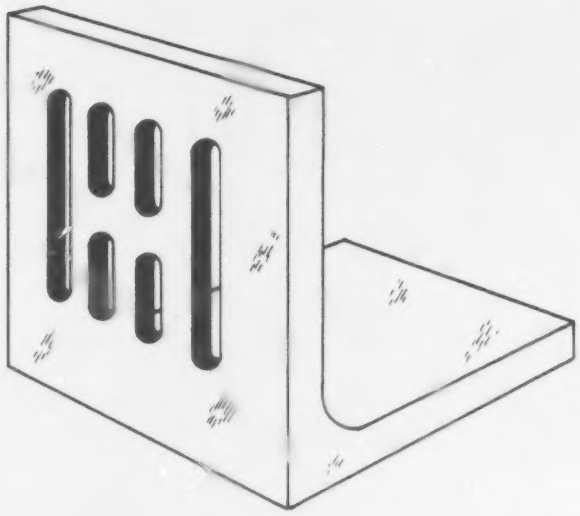


Then, he/she marks the center of the hole with a center punch and a hammer. He/she uses the hammer to make a dent in the part with the center punch.



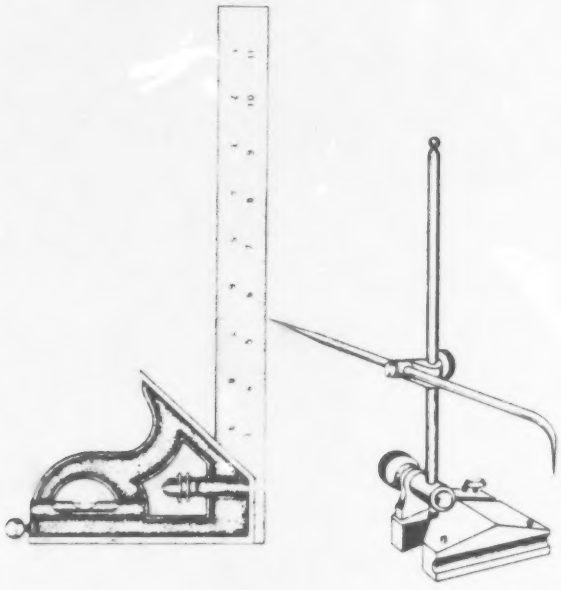
The dent in the part will guide the drill bit to the center of the hole.

Sometimes, the machinist uses an ANGLE PLATE to hold a part for layout.



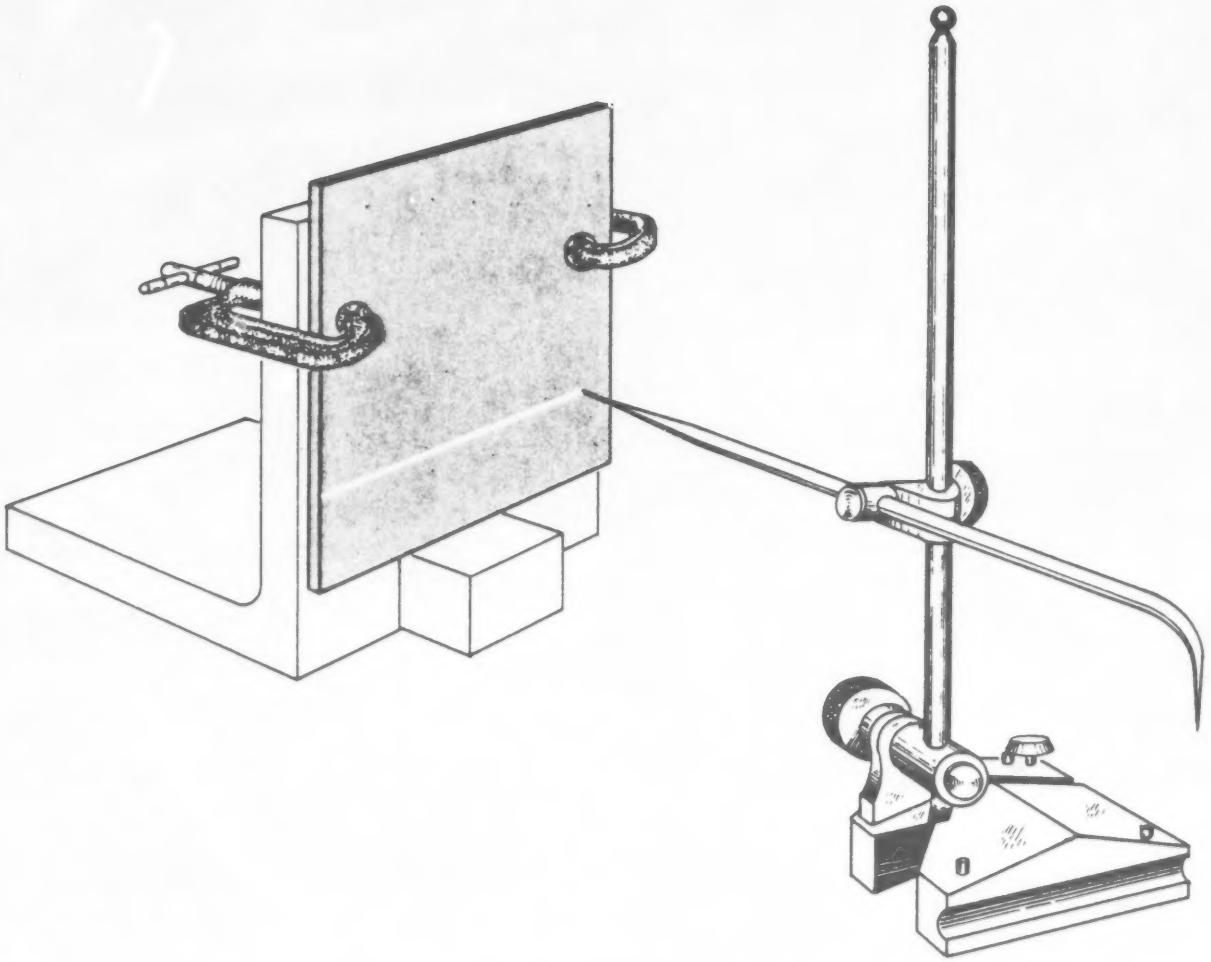
Companies make angle plates to very exact specifications.
Angle plates have a 90° corner.

Sometimes, the machinist use a SURFACE GAGE and a scriber to lay out exact dimensions on a part.



First, the machinist adjusts the scriber on the surface gage to the correct dimension.
Then, he/she marks the exact dimension on the part.

Here, the machinist uses an angle plate and a surface gage and scriber to lay out an exact dimension on a part.



Machine Shop Fundamentals

6C

UNIT 6: Layout

LESSON 6C: Precision Layout

OBJECTIVES:

1. The student will write the correct definition of layout.
2. The student will match the name of a precision layout tool to a picture of that layout tool.
3. The student will choose the correct precision layout tool from a description of that layout tool.

PROCEDURES:

1. Read the Objectives.
2. Read the Lesson.
3. Watch the teacher's Demonstration.
4. Do the Study Questions.
5. Do the Worksheets.
6. Do the Review Questions.
7. Do the Self-Test.

REFERENCES:

INTRODUCTION

What is layout?

Marking exact dimensions on a part is called layout.

The machinist marks an exact dimension on a part with a line.
This line is called a layout line.

For semiprecision layout, the machinist uses semiprecision measurement tools and semiprecision layout tools.

For precision layout, the machinist uses precision measurement tools and precision layout tools.

To lay out a part, a machinist follows these steps:

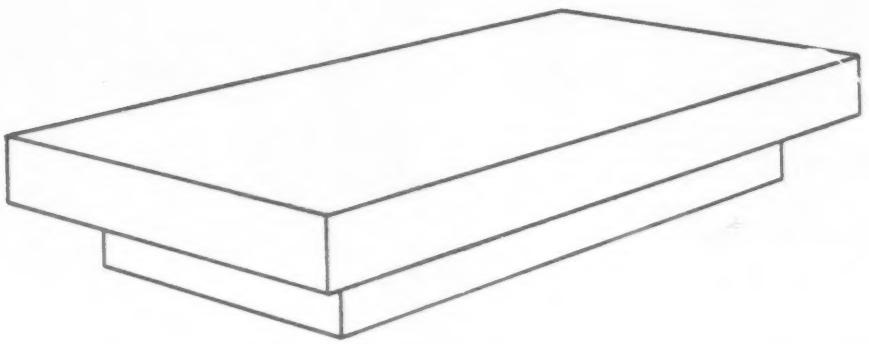
STEP 1. Clean the surfaces on the part.

STEP 2. Brush or spray layout dye on the part.

STEP 3. Mark the exact dimensions on the part with layout lines.

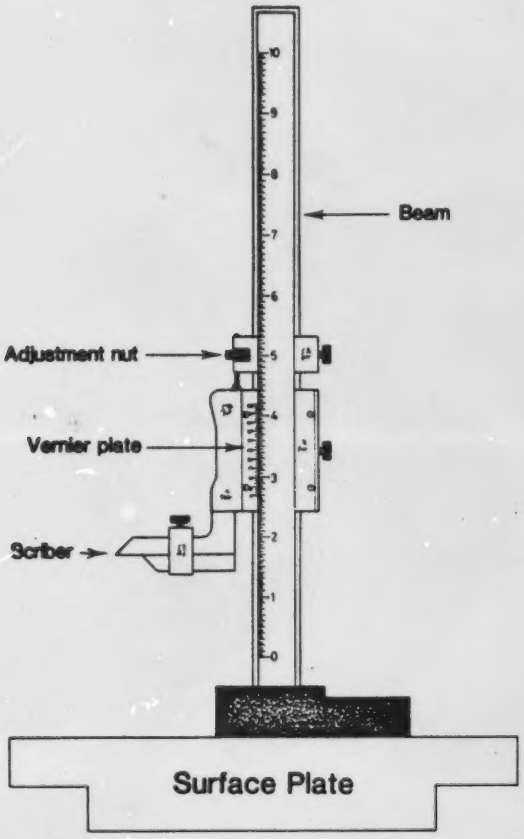
PRECISION LAYOUT

The machinist reads the blueprint to find the exact dimensions of the finished part.
For precision layout, the machinist uses a SURFACE PLATE.

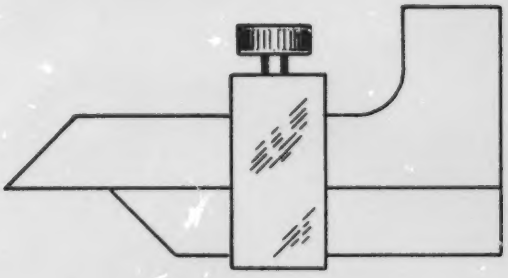


A surface plate is very flat and smooth.
Most surface plates are flat to $\pm$ .00001"

For most precision layout, the machinist uses a VERNIER HEIGHT GAGE and a surface plate.

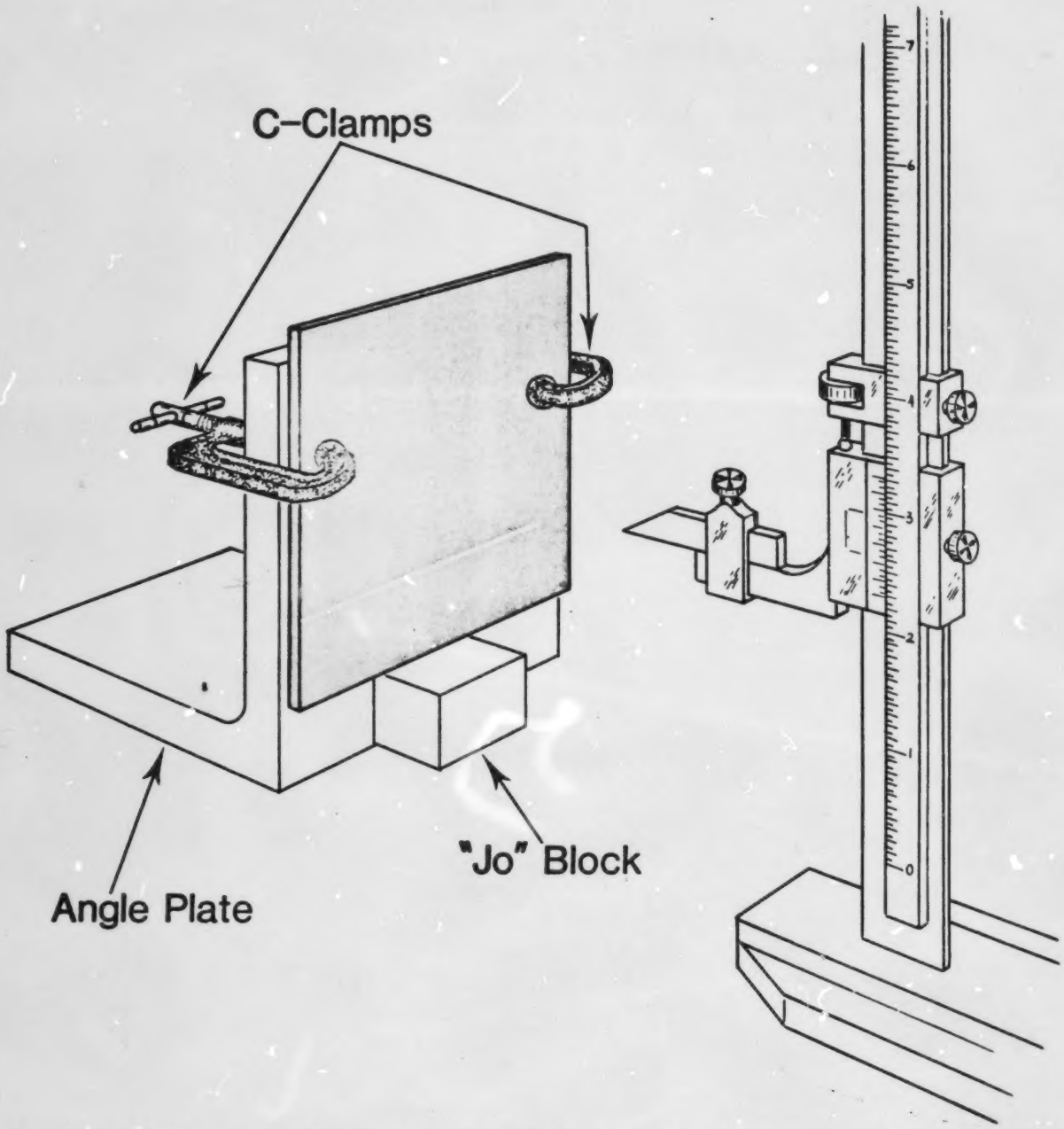


The vernier height gage has a scriber.



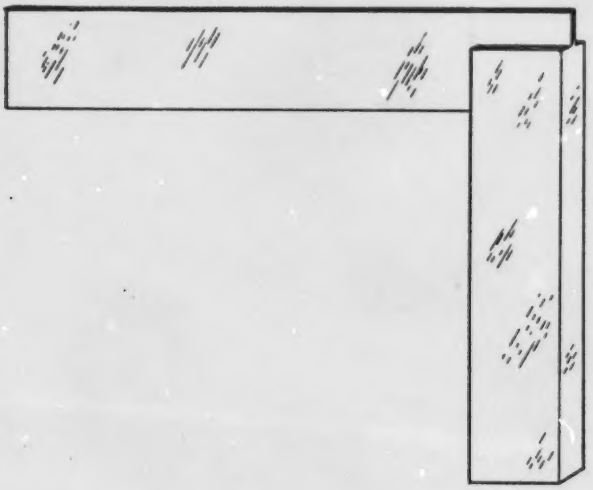
The machinist sets the scriber to lay out an exact dimension on a part.

Here, the machinist used an angle plate, 2 C-clamps, and a "Jo" Block to hold a part on the surface plate.

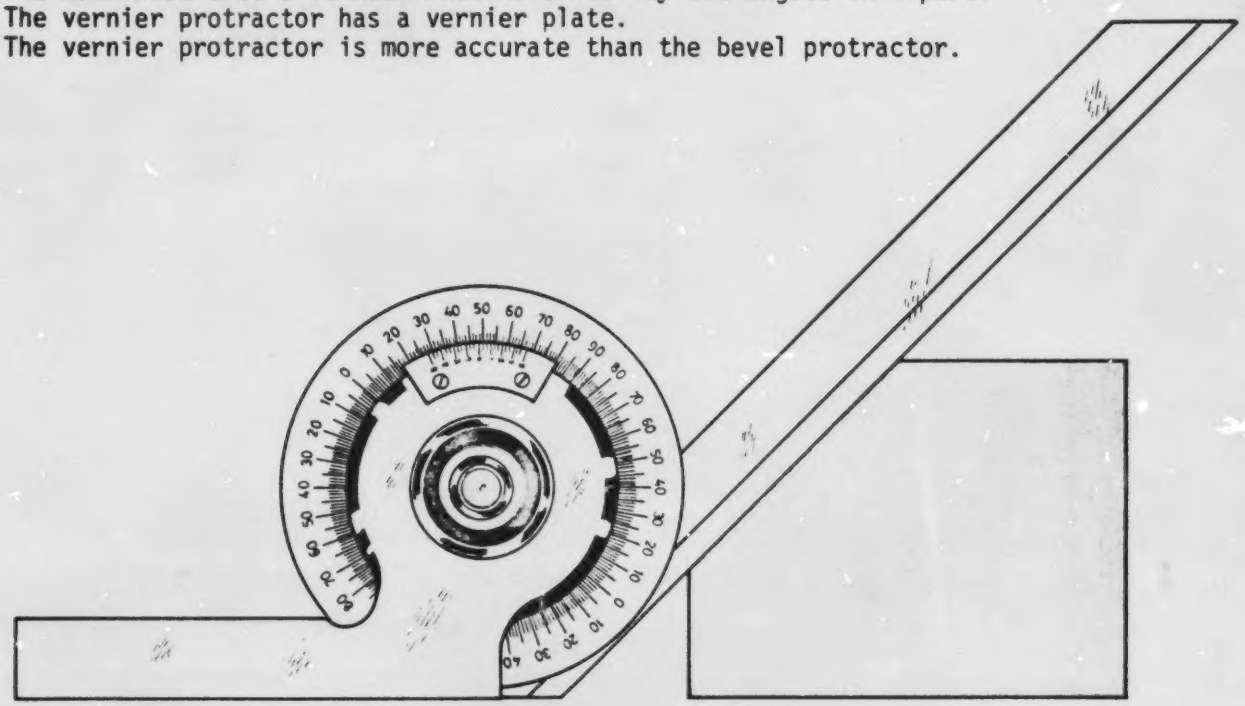


First, the machinist read the blueprint to find the exact dimension of the part.
Then, he/she set up the part on the surface plate with an angle plate, 2 C-clamps, and a "Jo" Block.
Next, he/she set the vernier height gage to the exact dimension.
Last, he/she marked the exact dimension on the part.

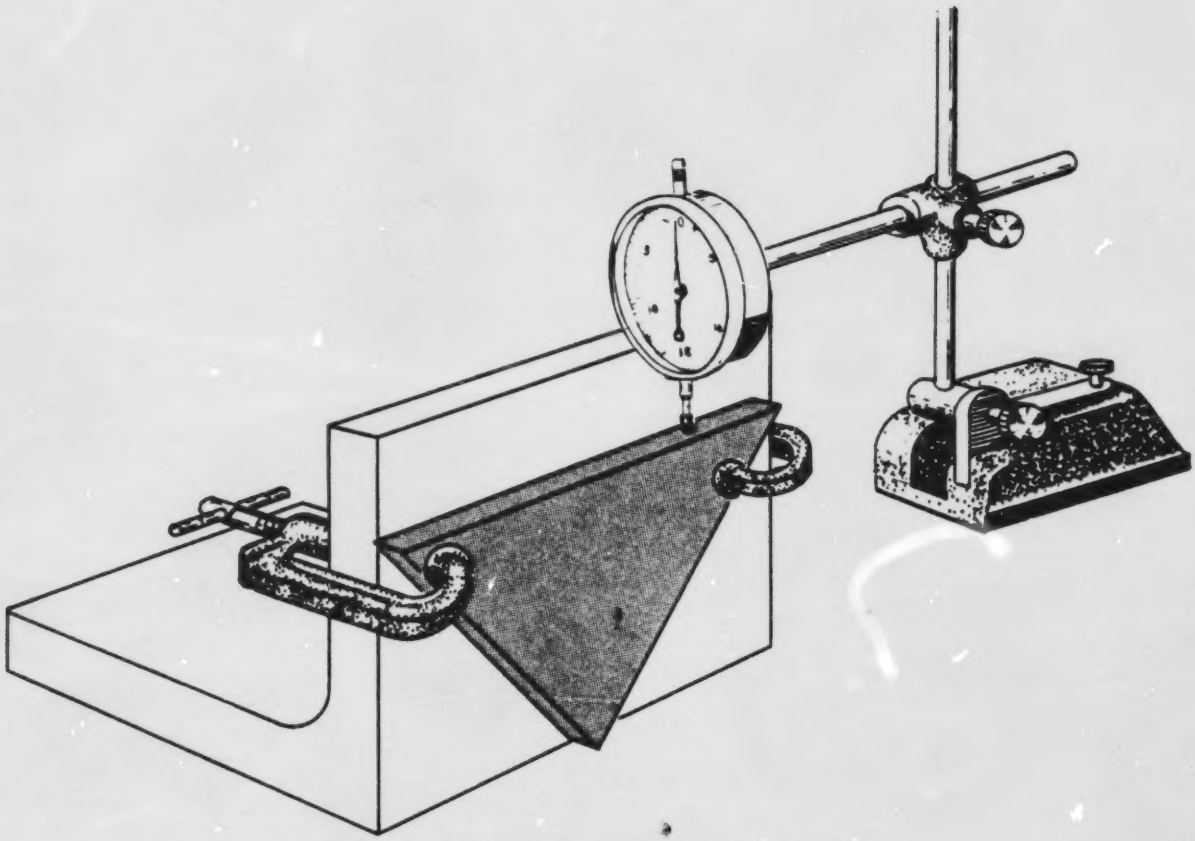
The machinist uses a MACHINIST'S SQUARE to lay out straight lines, 90° corners, and parallel lines on a part.
The machinist's square is more accurate than the combination square.



The machinist uses a VERNIER PROTRACTOR to lay out angles on a part.
The vernier protractor has a vernier plate.
The vernier protractor is more accurate than the bevel protractor.



Sometimes, the machinist uses a DIAL INDICATOR to set up the part before he/she lays out the part.



Machine Shop Fundamentals

7A

UNIT 7: Bench Tools

LESSON 7A: Wrenches, Pliers, and Screwdrivers

OBJECTIVES:

1. The student will write the 3 ways a machinist uses bench tools.
2. The student will match the correct name of a wrench to a picture of that wrench.
3. The student will match the correct name of a pair of pliers to a picture of that pair of pliers.
4. The student will match the correct name of a screwdriver to a picture of that screwdriver.
5. The student will choose the correct safety rules for using wrenches, pliers and screwdrivers.

PROCEDURES:

1. Read the Objectives.
2. Read the Lesson.
3. Watch the teacher's Demonstration.
4. Do the Study Questions.
5. Do the Worksheets.
6. Do the Review Questions.
7. Do the Self-Test.

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1. To set up machine tools
2. To do operations with a machine tool
   (The machinist uses bench tools together with machine tools to do an operation.)
3. To do operations by hand

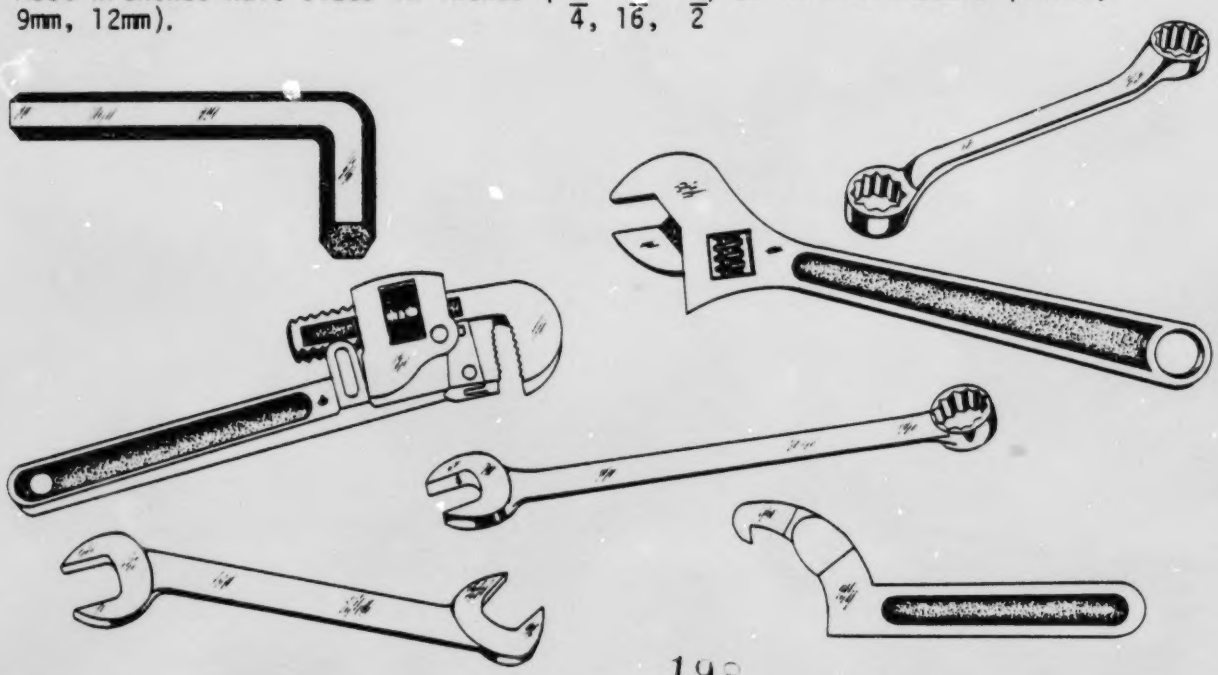
The machinist must choose the correct bench tool for each task.
He/she must learn how to use each bench tool correctly.
He/she must follow the safety rules for each bench tool.
He/she must practice using each bench tool.

Many times, the machinist must loosen and tighten bolts, nuts, setscrews and screws to set up a machine tool or to adjust a machine tool.
To loosen and tighten bolts, nuts, setscrews and screws, the machinist many times uses these bench tools:

1. Wrenches
2. Pliers
3. Screwdrivers

WRENCHES

There are many different kinds and sizes of wrenches.
Most wrenches have sizes in inches ($\frac{1}{4}$, $\frac{5}{16}$, $\frac{1}{2}$) or in millimeters (4.5mm, 9mm, 12mm).



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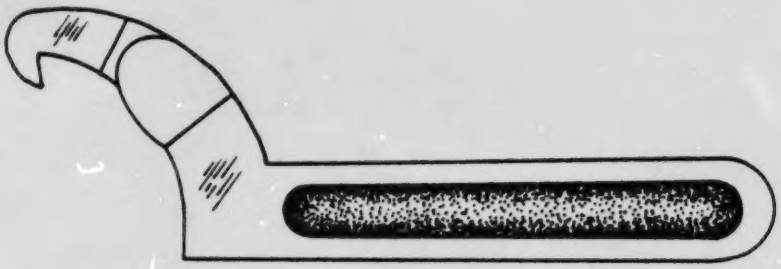
OPEN END WRENCHES

BOX END WRENCHES

COMBINATION WRENCHES

Some machine tools have special nuts or special bolts.
These special nuts and bolts do not have square heads or hexagonal heads.
The machinist uses a SPANNER WRENCH to loosen and tighten these special nuts and special bolts.

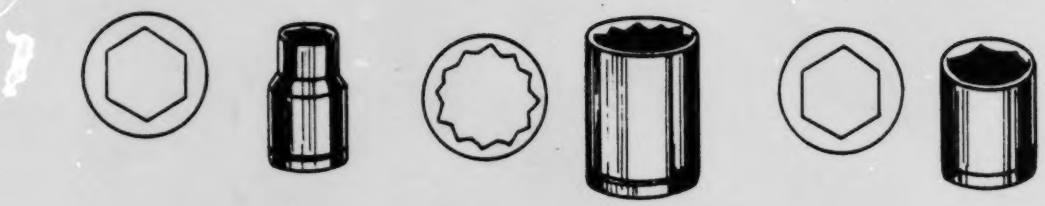
SPANNER WRENCHES



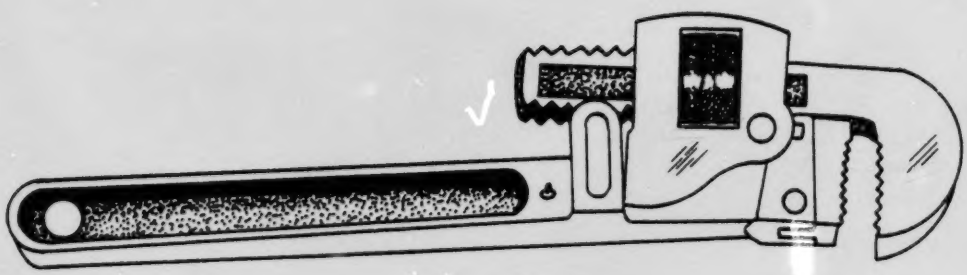
SETSCREW WRENCHES (Allen Wrenches or Hex Keys)

The machinist must choose the correct wrench for the job.

SOCKET WRENCHES



PIPE WRENCHES



ADJUSTABLE WRENCHES (Crescent Wrenches)

Always pull the handle of the adjustable wrench toward the adjustable jaw.

PLIERS

There are many different kinds and sizes of pliers.

Pliers <u>are not</u> wrenches.

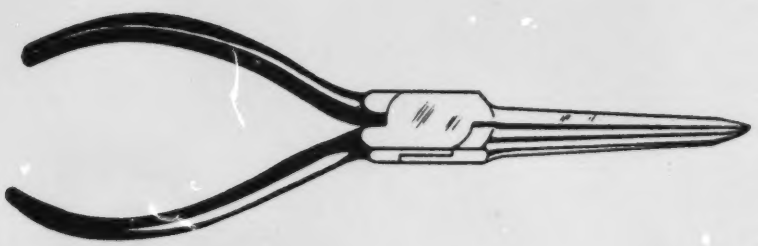
The machinist <u>does not</u> use pliers instead of wrenches.

Always choose the correct bench tool for each task.

The machinist uses pliers to hold small parts, to bend small parts, and to cut metal wire.

COMBINATION PLIERS

NEEDLE NOSE PLIERS



DIAGONAL PLIERS

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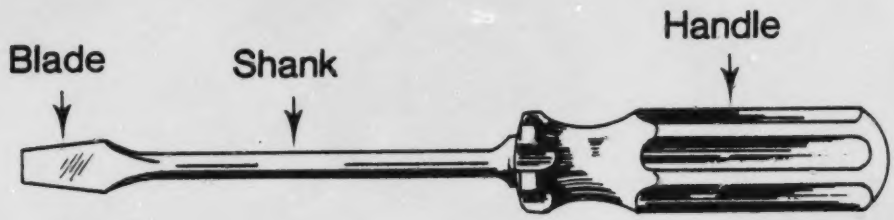
SCREWDRIVERS

There are many different kinds and sizes of screwdrivers.
The machinist uses a screwdriver to loosen and to tighten screws.

Most screwdrivers have 3 main parts:

1. THE HANDLE
2. THE SHANK
3. THE BLADE



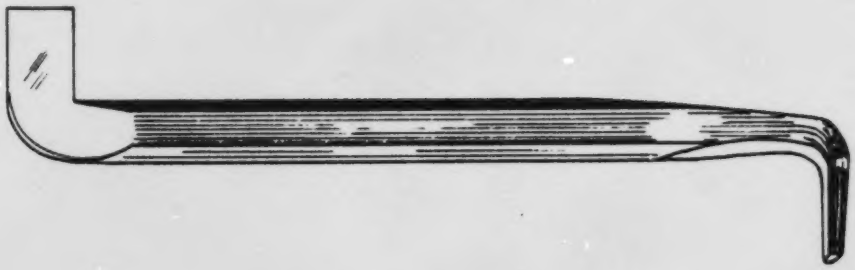
STANDARD SCREWDRIVERS

There are many sizes and lengths of standard screwdrivers.

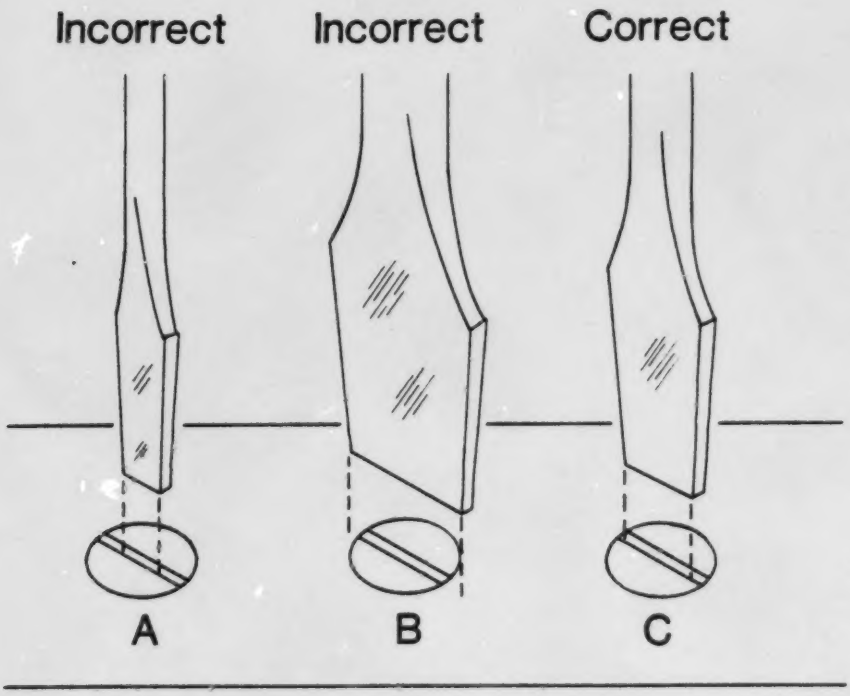
PHILLIPS SCREWDRIVERS

There are many sizes and lengths of Phillips screwdrivers.

OFFSET SCREWDRIVERS



The machinist must choose the correct screwdriver for the job.
He/she must match the screwdriver blade to the head of the screw.



If the blade of the standard screwdriver is worn, the machinist must grind (sharpen) the blade to the correct specifications.

SAFETY RULES

1. Always wear your safety glasses.
2. Learn how to correctly use a bench tool before you use it.
3. Choose the correct bench tool for the task.

Wrenches

4. Choose the correct wrench for the task.
5. Choose the correct size wrench for the task.
6. Always pull on a wrench.
7. Do not hit a wrench with a hammer.

Pliers

8. Do not use a pair of pliers when you should use a wrench.

Screwdrivers

9. Choose the correct screwdriver for the task.
10. Choose the correct size screwdriver blade for the head of the screw.
11. Do not use a screwdriver with a worn blade.
12. Do not use a screwdriver like a chisel.
13. Do not hit a screwdriver with a hammer.
14. Do not use a screwdriver to pry things open.

SUMMARY

The machinist uses bench tools (hand tools) to do many different tasks (jobs). He/she uses bench tools in 3 ways:

1. To set up machine tools
2. To do operations with a machine tool
   (The machinist uses bench tools together with machine tools to do an operation.)
3. To do operations by hand.

The machinist must choose the correct bench tool for each task.
He/she must learn how to use each bench tool correctly.
He/she must follow the safety rules for each bench tool.
He/she must practice using each bench tool.

Many times, the machinist must loosen and tighten bolts, nuts, setscrews and screws to set up a machine tool or to adjust a machine tool.
To loosen and tighten bolts, nuts, setscrews and screws, the machinist many times uses these bench tools:

1. WRENCHES
   Open End Wrenches
   Box End Wrenches
   Combination Wrenches
   Spanner Wrenches
   Setscrew Wrenches (Allen Wrenches or Hex Keys)
   Socket Wrenches
   Pipe Wrenches
   Adjustable Wrenches (Crescent Wrenches)

2. PLIERS
   Combination Pliers
   Needle Nose Pliers
   Diagonal Pliers

3. SCREWDRIVERS
   Standard Screwdrivers
   Phillips Screwdrivers
   Offset Secrewdrivers

Machine Shop Fundamentals

7B

UNIT 7: Bench Tools

LESSON 7B: Vises, Clamps, and V-blocks

OBJECTIVES:

1. The student will match the name of a vise to a picture of that vise.
2. The student will match the name of a clamp to a picture of that clamp.
3. The student will match the name of a V-block to a picture of that V-block.

PROCEDURES:

1. Read the Objectives.
2. Read the Lesson.
3. Watch the teacher's Demonstration.
4. Do the Study Questions.
5. Do the Worksheets.
6. Do the Review Questions.
7. Do the Self-Test.

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1. To set up machine tools
2. To do operations with a machine tool (The machinist uses bench tools together with machine tools to do an operation.)
3. To do operations by hand

The machinist must choose the correct bench tool for each task.

He/she must learn how to correctly use each bench tool.

He/she must follow the safety rules for each bench tool.

He/she must practice using each bench tool.

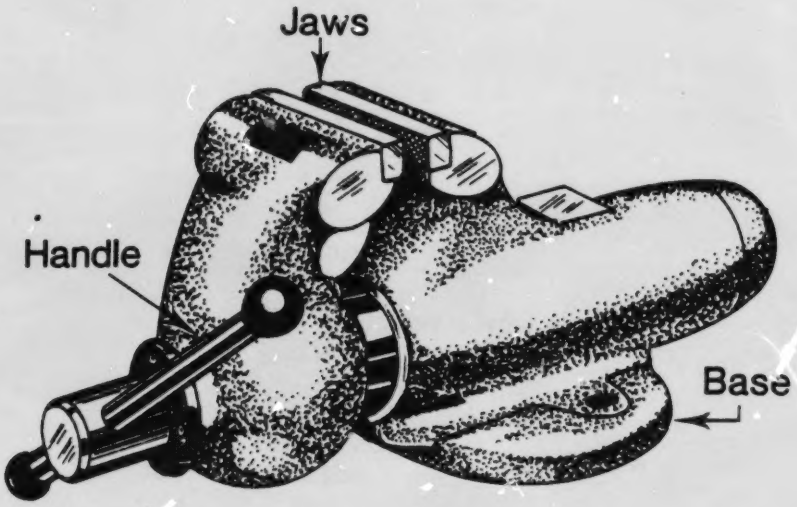
Many times, the machinist uses bench tools to hold parts. To hold parts, there are 3 main kinds of bench tools:

1. VISES
2. CLAMPS
3. V-BLOCKS

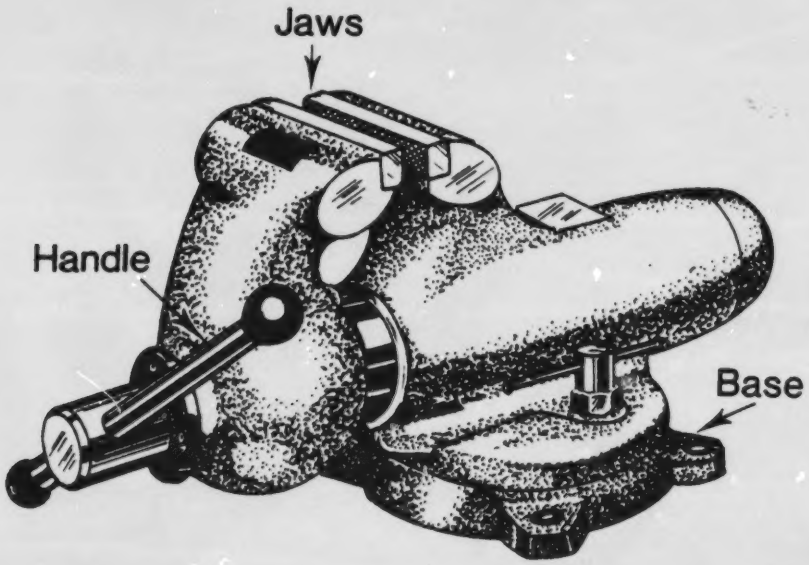
In some textbooks, vises, clamps, and V-blocks are called CLAMPING DEVICES or WORK HOLDING DEVICES.

VISES

There are many different kinds and sizes of vises.

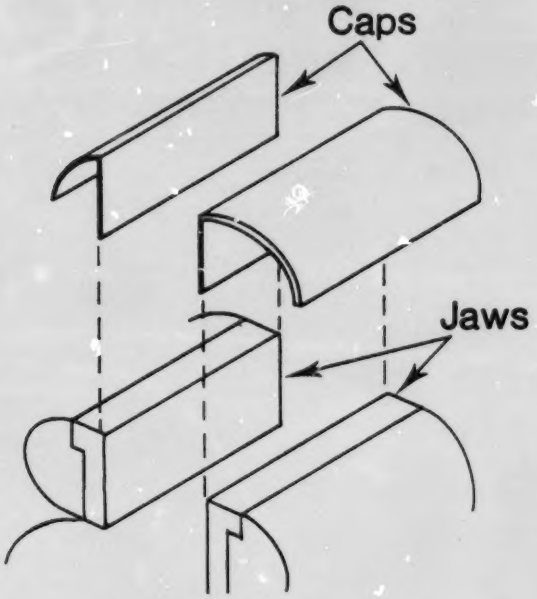


This is a BENCH VISE.
This bench vise has a solid base.

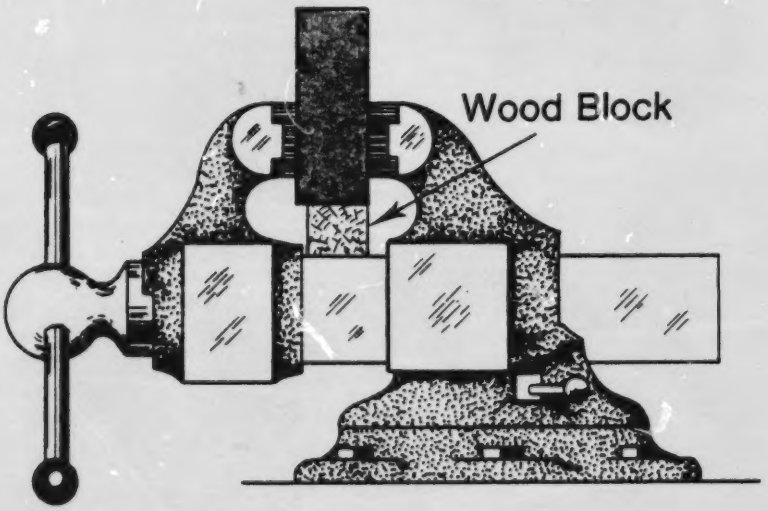


This is also a BENCH VISE.
This bench vise has a swivel base.

The jaws of a bench vise are very hard.
The jaws will scratch, dent, and damage parts made of soft metals.
The jaws will scratch, dent, and damage smooth surfaces on parts.



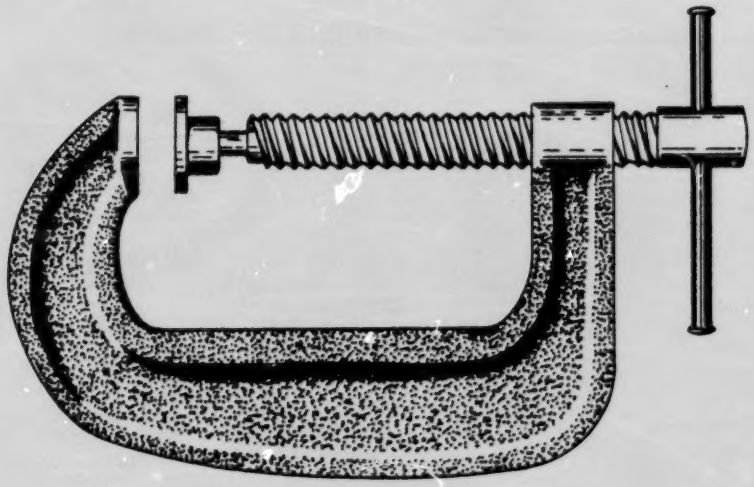
Many times, the machinist puts CAPS over the jaws of the bench vise.
The caps protect parts made of soft metals, and they protect smooth surfaces on parts.



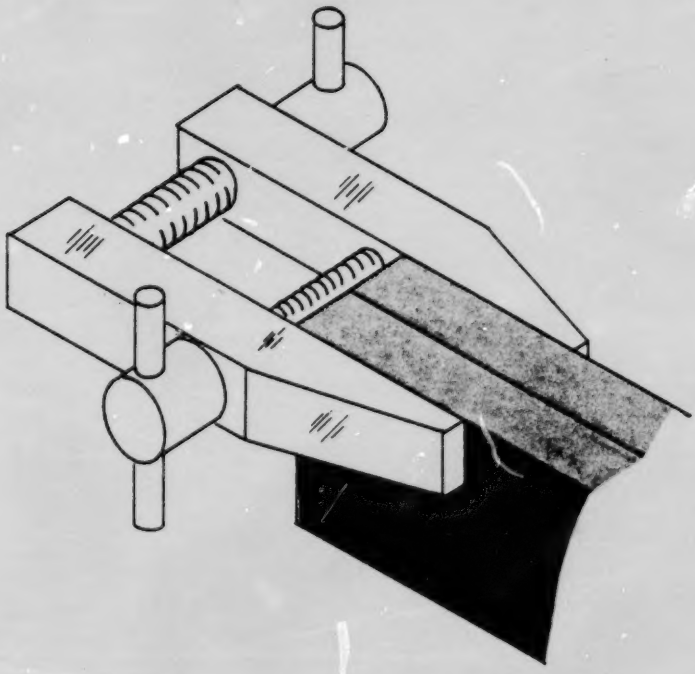
Sometimes, the machinist uses WOOD BLOCKS to hold the part in the jaws of a bench vise.

CLAMPS

There are many different kinds and sizes of CLAMPS.
The most common clamp is the C-CLAMP.



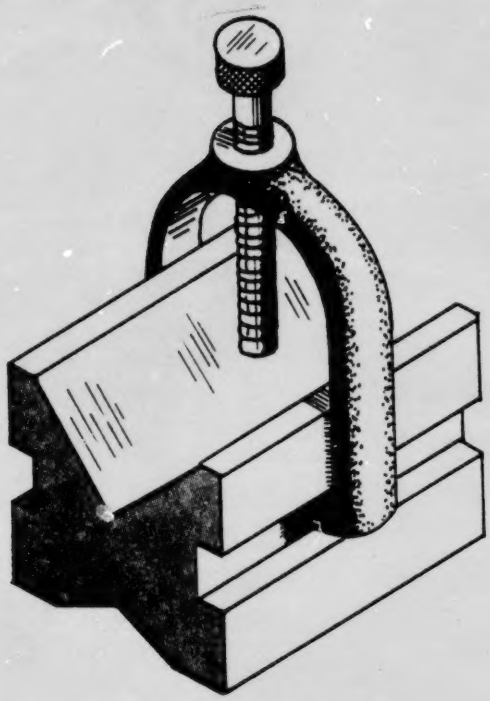
Sometimes, the machinist uses a PARALLEL CLAMP to hold small parts.



The jaws of the parallel clamp must be parallel to hold the part tightly.

V-BLOCKS

Many times, the machinist uses a V-BLOCK and a clamp to hold a round part.



SUMMARY

Many times, the machinist uses bench tools to hold parts.
To hold parts, there are 3 main kinds of bench tools:

1. VISES
   Bench vises with a solid base
   Bench vises with a swivel base

2. CLAMPS
   C-clamps
   Parallel clamps

3. V-BLOCKS

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Machine Shop Fundamentals

7C

UNIT 7: Bench Tools

LESSON 7C: Hacksaws and Hacksaw Blades

OBJECTIVES:

1. The student will write the correct definition of pitch for a hacksaw blade.
2. The student will choose correct pitch of a hacksaw blade from a picture of the hacksaw blade and the part.
3. The student will choose the correct position to set up a part in a vise from a picture of the part and the vise.
4. The student will choose the correct safety rules to use hacksaws.

PROCEDURES:

1. Read the Objectives.
2. Read the Lesson.
3. Watch the teacher's Demonstration.
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3. To do operations by hand.

The machinist must choose the correct bench tool for each task.

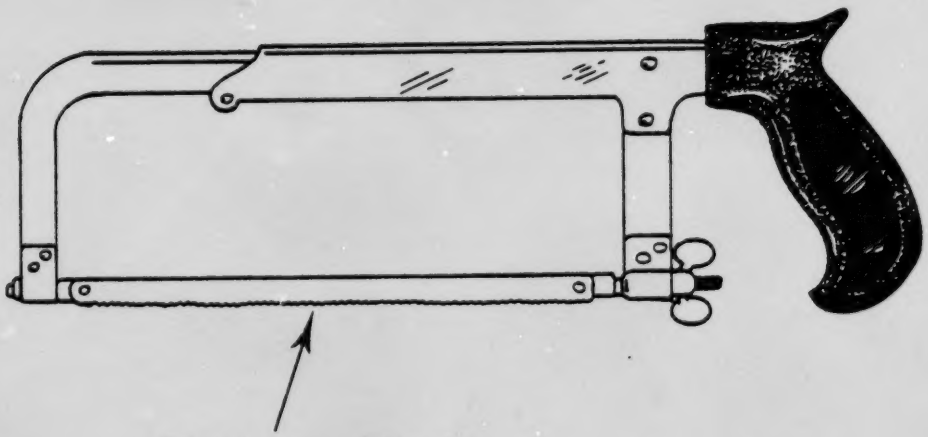
He/she must learn how to correctly use each bench tool.

He/she must follow the safety rules for each bench tool.

He/she must practice using each bench tool.

Sometimes, the machinist must saw a metal part by hand.
To saw metal parts by hand, the machinist uses a HAND HACKSAW.

HACKSAW

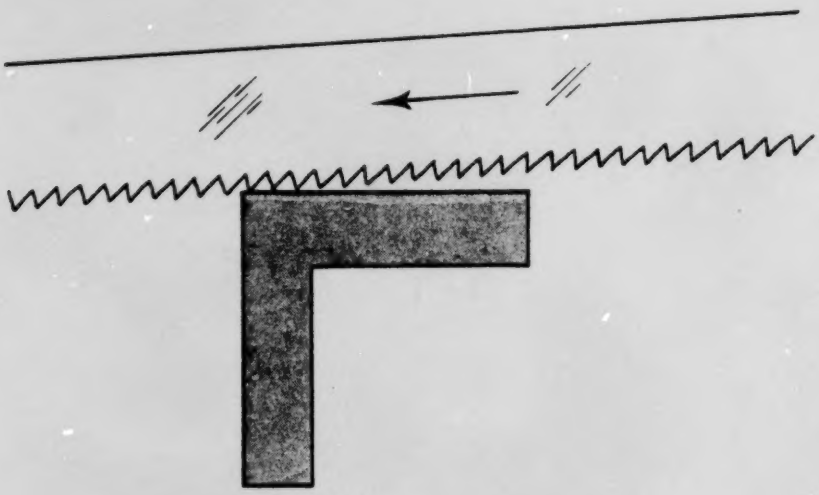


The machinist uses a hand hacksaw to saw different kinds of metals.

HACKSAW BLADES

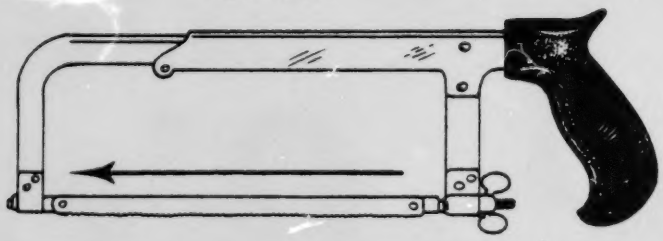
Hacksaw blades are very hard and very brittle.

Hacksaw blades cut in only one direction.

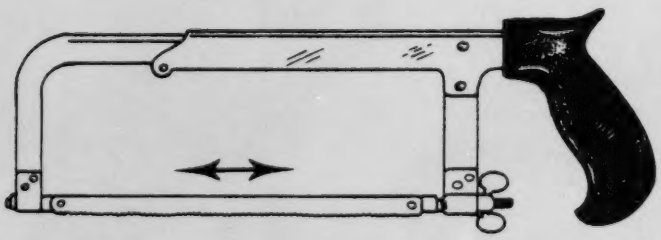


The machinist uses most of the teeth on the hacksaw blade to make a good, fast cut.

CORRECT



INCORRECT



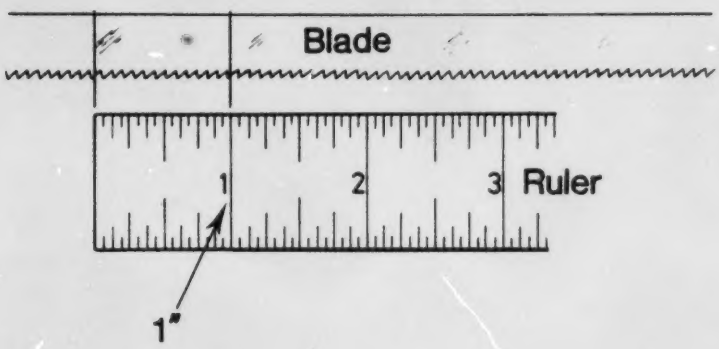
The machinist must choose the correct hacksaw blade for each task.

The machinist must think about 2 factors to choose the correct hacksaw blade:

1. The kind of metal of the part
2. The shape and thickness of the part

The machinist must choose a hacksaw blade with the correct PITCH for each task.

Pitch

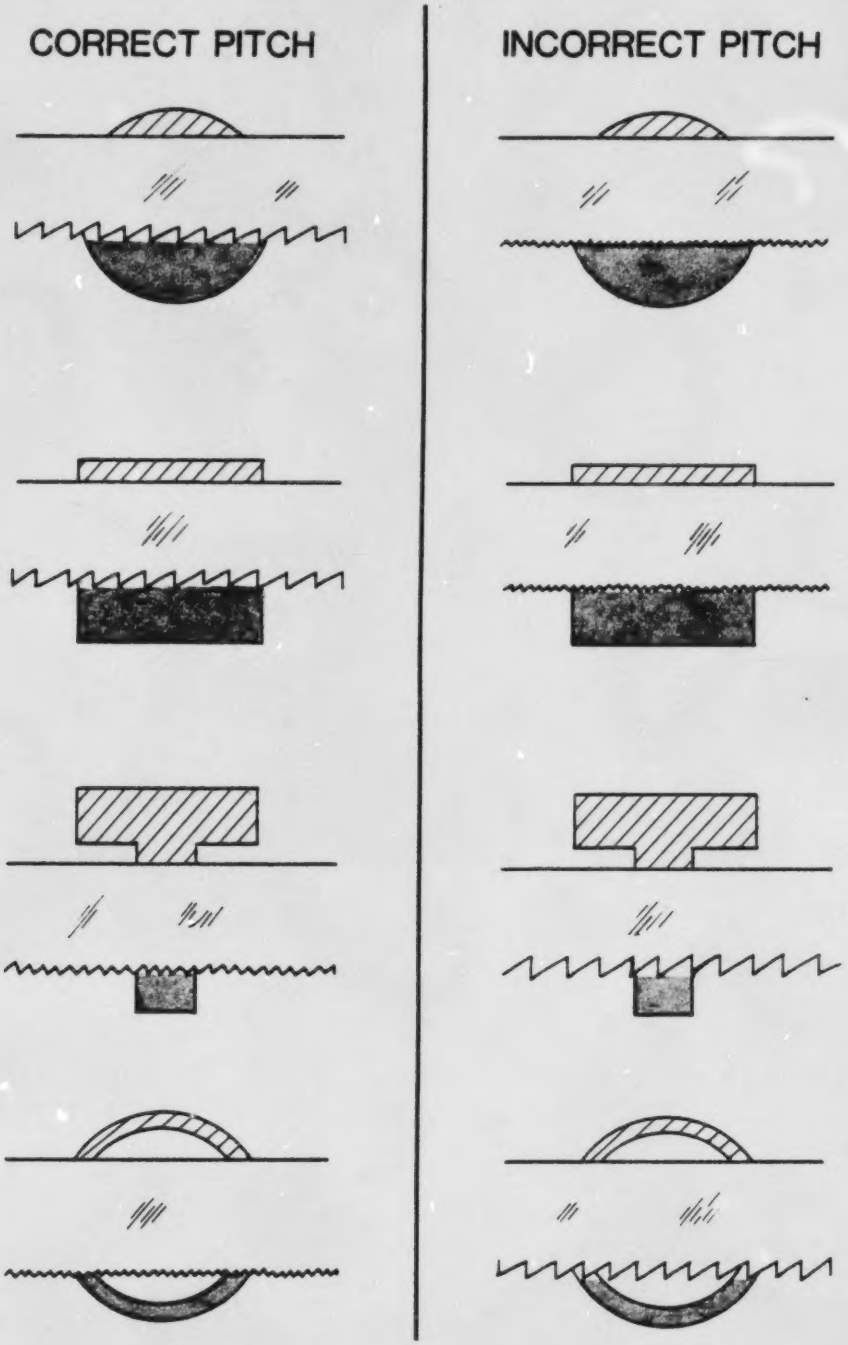


The number of teeth in one inch on the hacksaw blade is called PITCH.

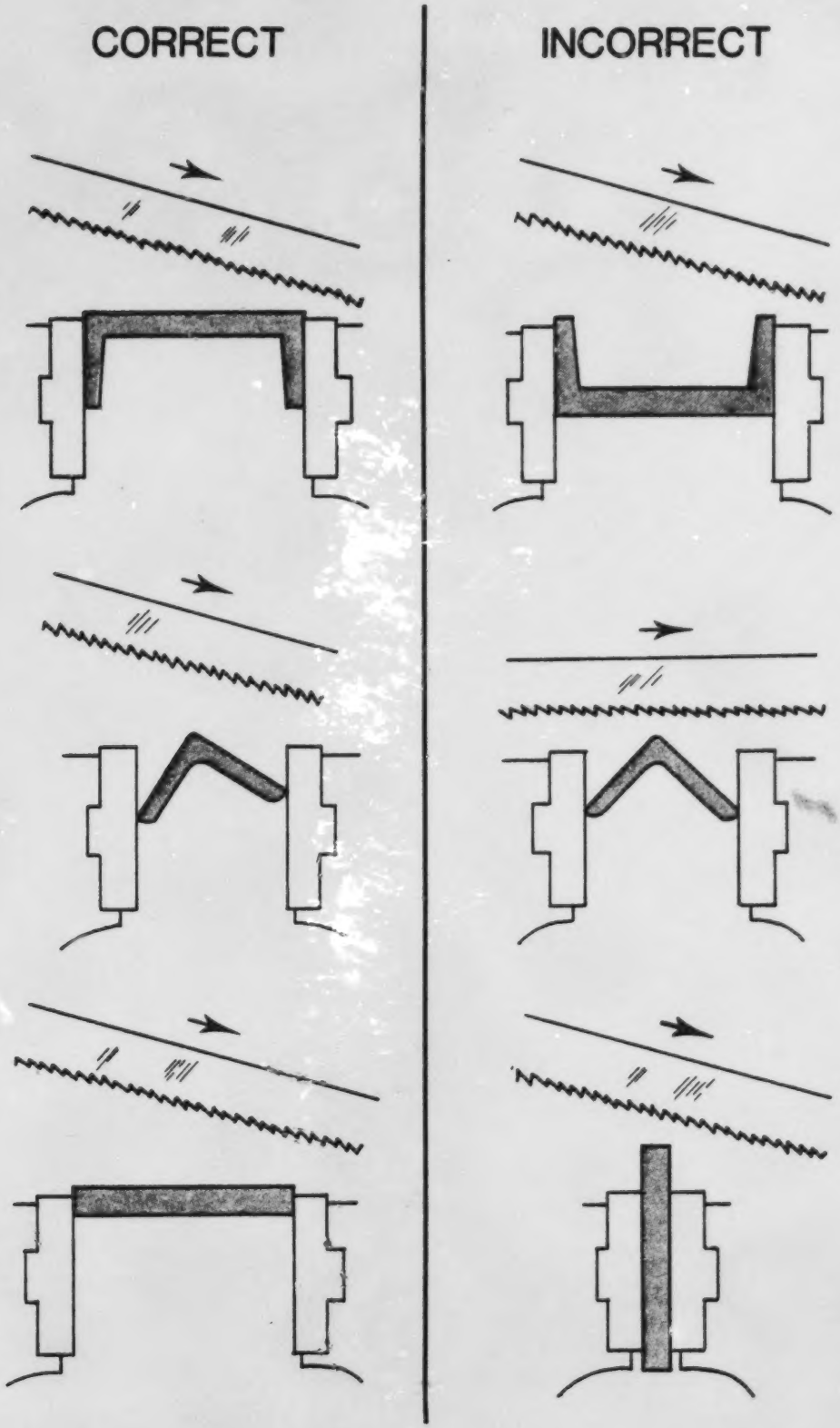
Companies make hacksaw blades with 4 standard pitches:

KIND OF METAL TO BE CUT	PITCH OF THE BLADE (TEETH PER INCH)	KIND OF PITCH
Low Carbon Steel Medium Carbon Steel	14	Coarse Pitch
Aluminum High Carbon Steel Cast Iron	18	Medium Pitch
Tin Brass Copper Channel Iron	24	Fine Pitch
Thin Metals	32	Very Fine Pitch

The machinist must also look at the shape and thickness of the part to choose a hacksaw blade with the correct pitch.

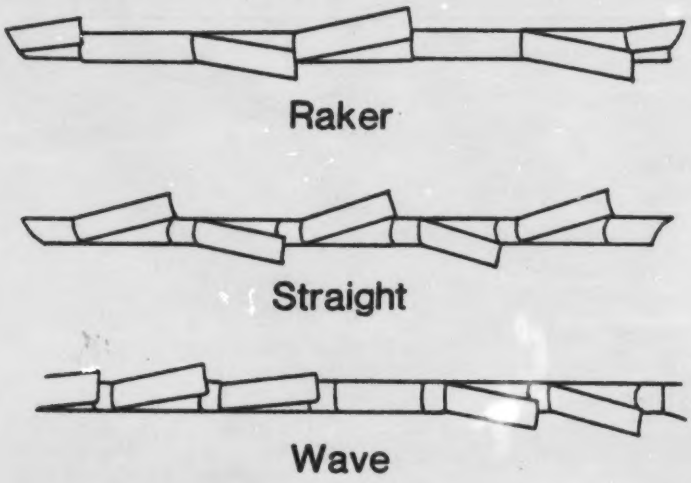


The correct pitch for each part has 2 or more teeth on the part at all times. Less than 2 teeth on the part will break the teeth on the hacksaw blade. But, too many teeth on the part will clog the teeth with metal chips.

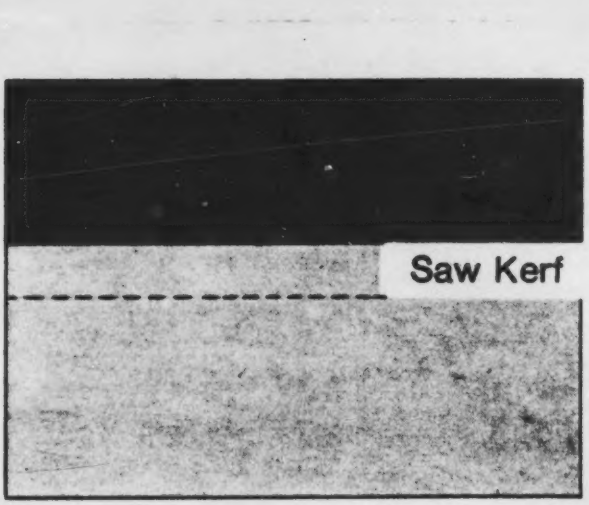

CORRECT
INCORRECT

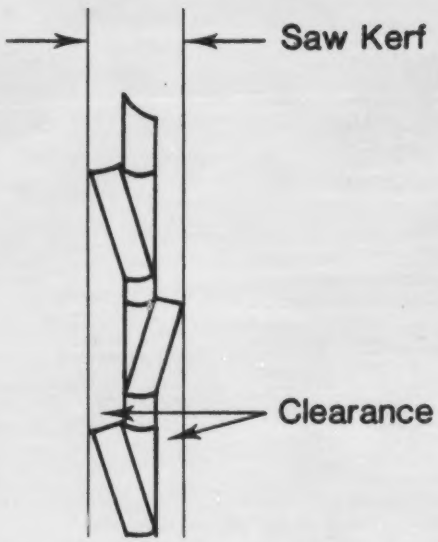
Teeth Sets

The teeth on hacksaw blades have different TEETH SETS.



The teeth make a cut or slot in the part.
This cut or slot in the part is called the SAW KERF.

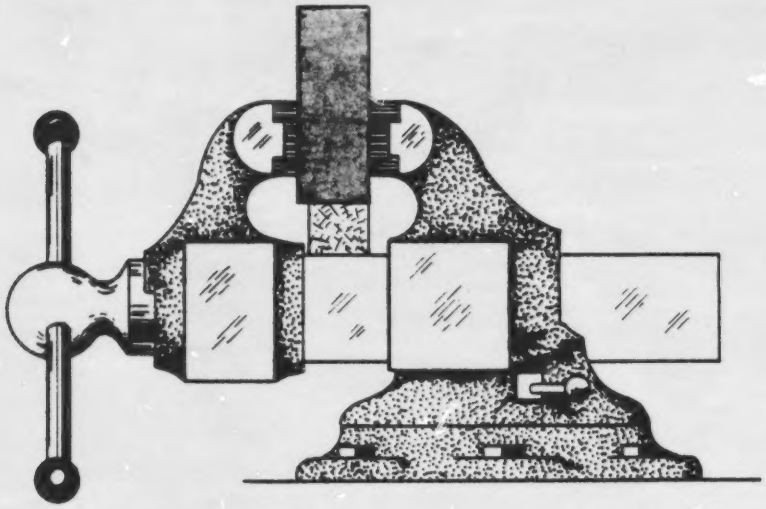




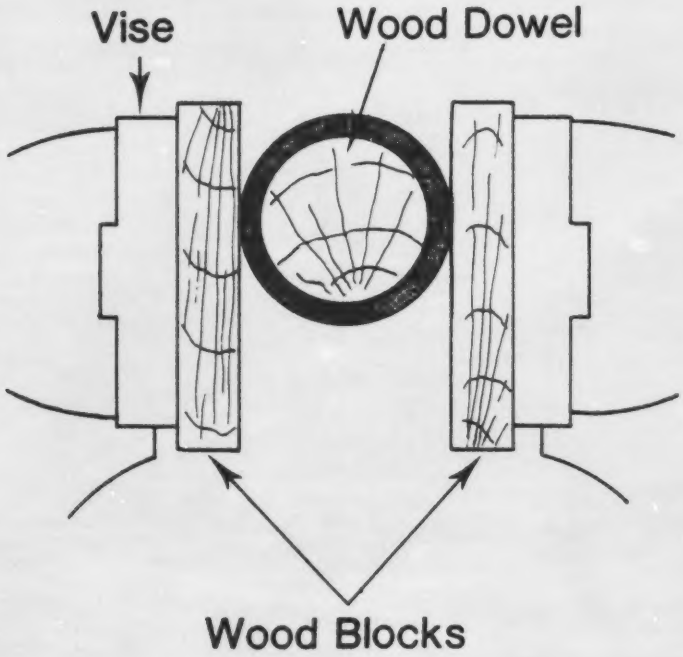
The saw kerf in the metal must be a little larger than the thickness of the hacksaw blade.
This cut gives the hacksaw blade CLEARANCE.
If the hacksaw blade does not have good clearance, the hacksaw blade cannot cut the part.

HOLDING THE PART

To make a good cut with a hacksaw, the part must not move.
Most of the time, the machinist uses a bench vise to hold the part.
To make a good cut and not break the teeth on the hacksaw blade, the machinist must correctly set up the part in the bench vise.



Sometimes, the machinist must cut thin tubing and thin metals.
He/she uses wood blocks and wood dowels to set up the part in the bench vise.



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SAFETY RULES

1. Always wear your safety glasses.
2. Learn how to correctly use a bench tool before you use it.
3. Choose a hacksaw blade with the correct pitch for each task.
4. Do not twist or bend a hacksaw blade.
   It will break if you twist or bend it.
5. Always use a bench vise to hold the part tightly
6. Do not use a hacksaw with a dull blade.
7. Do not touch a part immediately after you saw it.
   Sawing makes the part very hot.

Machine Shop Fundamentals

7D

UNIT 7: Bench Tools

LESSON 7D: Hammers, Chisels, and Punches

OBJECTIVES:

1. The student will match the name of a hammer to a picture of that hammer.
2. The student will match the name of a chisel to a picture of that chisel.
3. The student will match the name of a punch to a picture of that punch.

PROCEDURES:

1. Read the Objectives.
2. Read the Lesson.
3. Watch the teacher's Demonstration.
4. Do the Study Questions.
5. Do the Worksheets.
6. Do the Review Questions.
7. Do the Self-Test.

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He/she uses bench tools in 3 ways:

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3. To do operations by hand.

The machinist must choose the correct bench tool for each task.

He/she must learn how to correctly use each bench tool.

He/she must follow the safety rules for each bench tool.

He/she must practice using each bench tool.

In this lesson, you will learn about these bench tools:

1. Hammers
2. Chisels
3. Punches

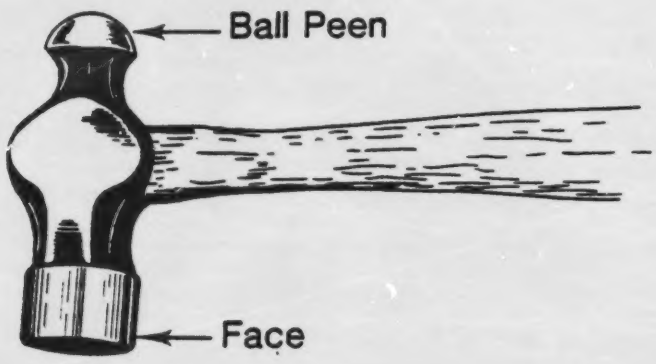
HAMMERS

In the machine shop, there are two main kinds of hammers:

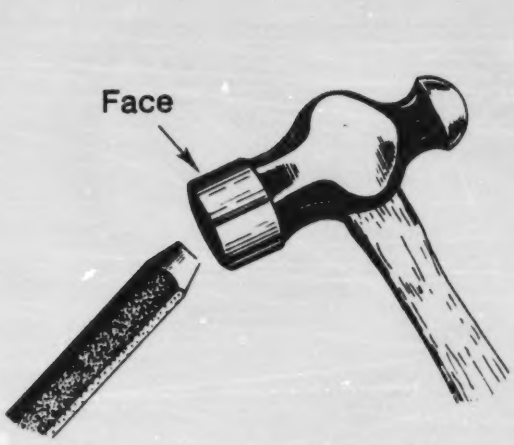
1. Hammers with a hard face
2. Hammers with soft faces

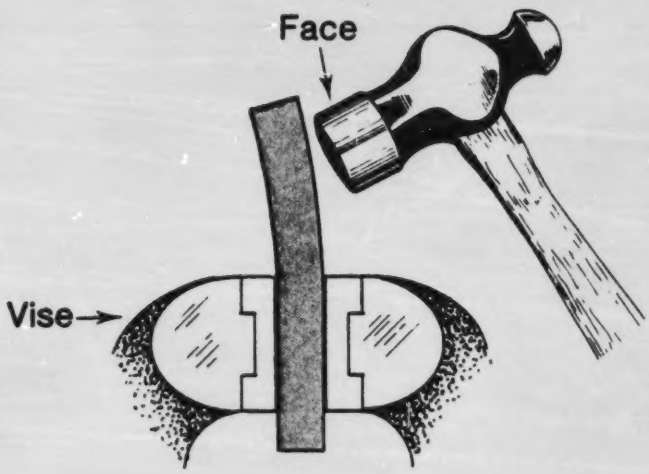
1. Hammers with a hard face

A BALL PEEN HAMMER has a very hard face.



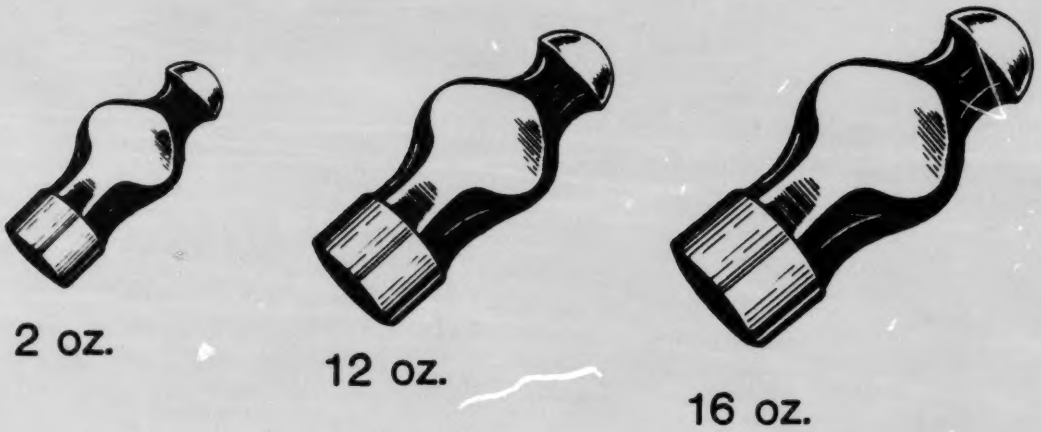
Many times, the machinist uses the face of the ball peen hammer to hit other bench tools or some metal parts.





Sometimes, the machinist uses the ball peen end of the ball peen hammer to PEEN parts.

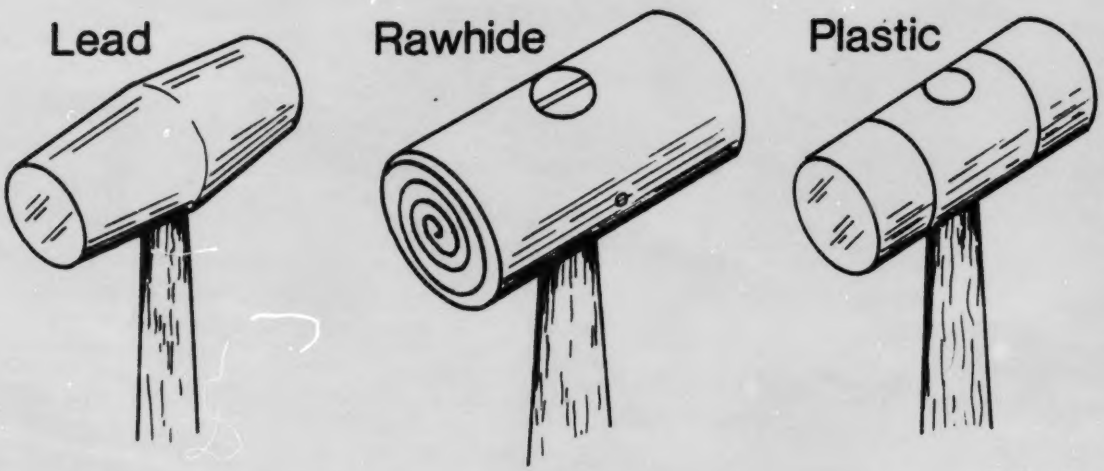
The size of a ball peen hammer is how much the head of the hammer weighs, without the wood handle.



Most common sizes of ball peen hammers are 2 oz. (ounces), 4 oz., 8 oz., 12 oz., 16 oz., or 1 lb. (pound), 1 $\frac{1}{4}$ lb., 1 $\frac{1}{2}$ lb., 2 lbs., and 3 lbs.

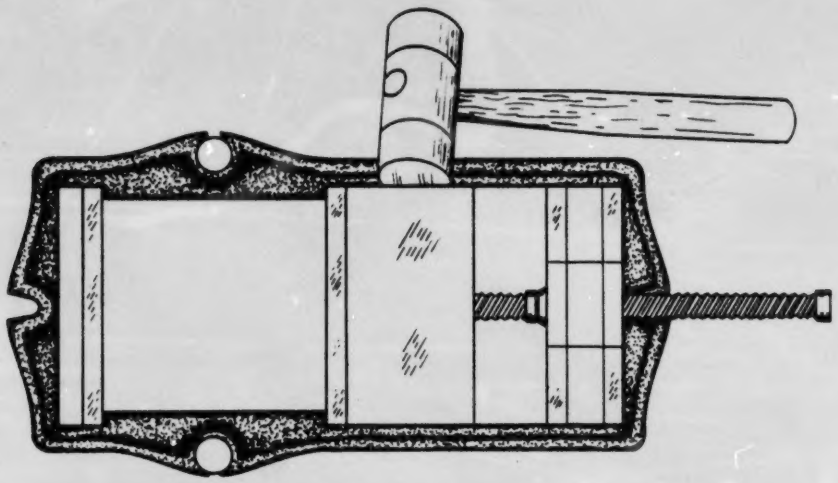
2. Hammers with soft faces

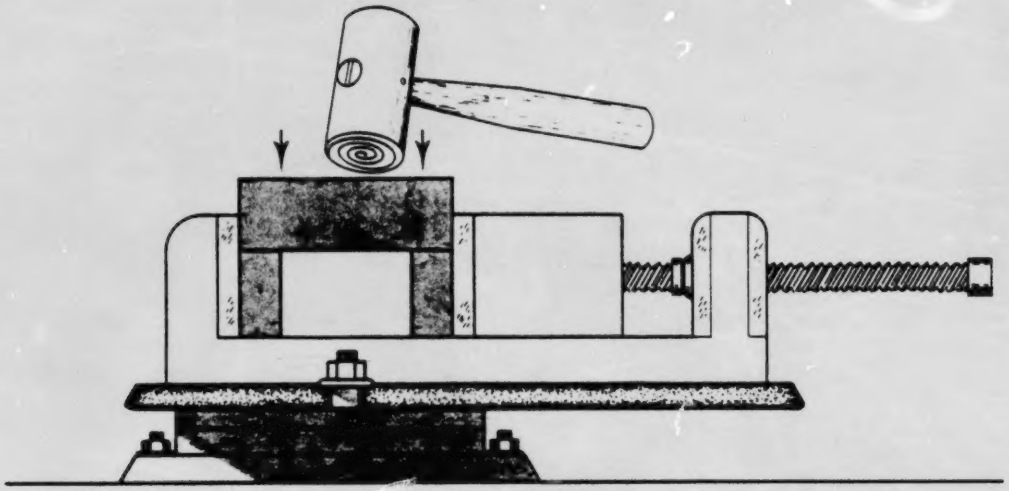
Hammers with soft faces are made from plastic, rubber, lead, copper or rawhide.

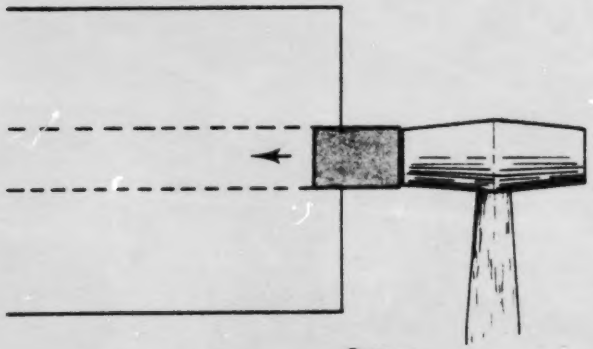


Some textbooks call a hammer with soft faces a MALLET.

Most of the time, the machinist uses hammers with soft faces to set up machine tools, to set up parts, and to assemble (put together) different parts.
When the machinist does not want to scratch, dent, or damage a surface on a part, he/she uses a hammer with soft faces.







CHISELS

The machinist uses CHISELS and a ball peen hammer to cut extra metal from a part.
Because chisels cut cold metal, some textbooks and machinists call them "COLD" CHISELS.
In the machine shop, cutting metal with a chisel is sometimes called CHIPPING.

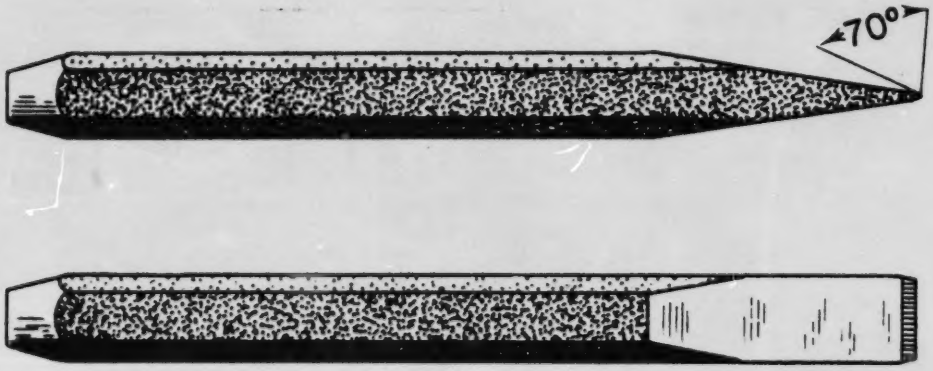
The machinist usually uses a vise to hold the part.

There are 4 main kinds of chisels:

1. THE FLAT CHISEL
2. THE CAPE CHISEL
3. THE ROUND NOSE CHISEL
4. THE DIAMOND POINT CHISEL

1. THE FLAT CHISEL

The flat chisel has a 40° - 70° point.



The machinist uses a flat chisel for general cutting and chipping work.

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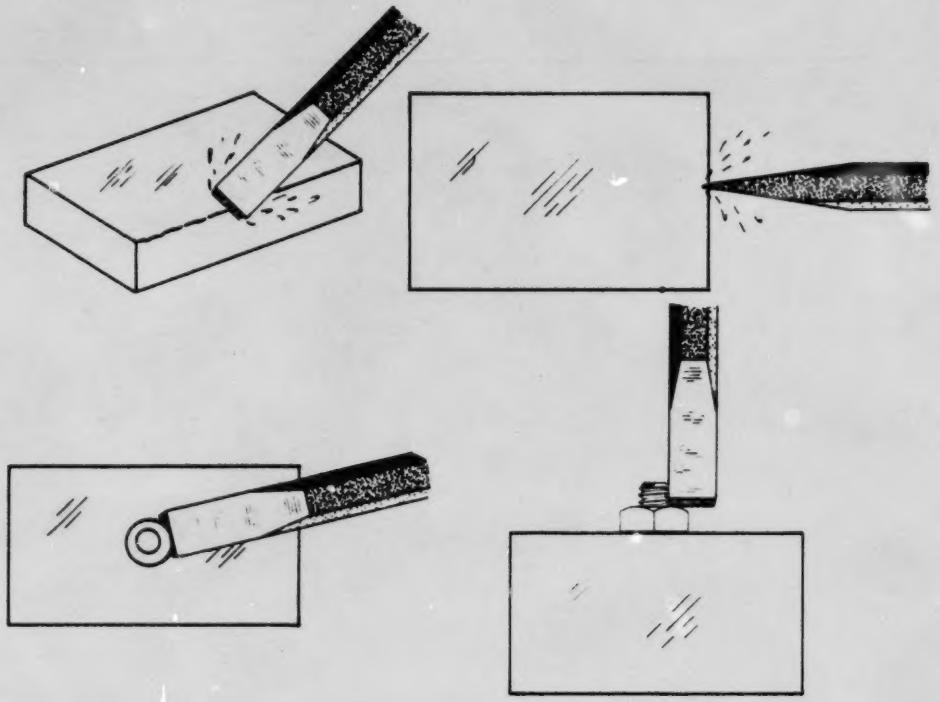
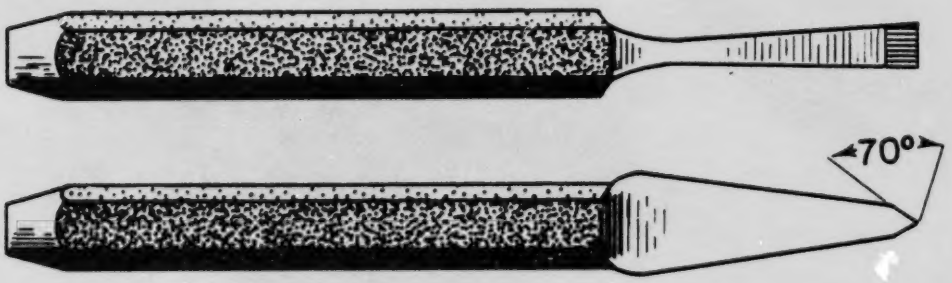
The machinist uses a flat chisel to cut off sharp edges on a part, to cut thin pieces of metal, to cut off the heads of rivets or bolts, and to cut off rusty nuts.

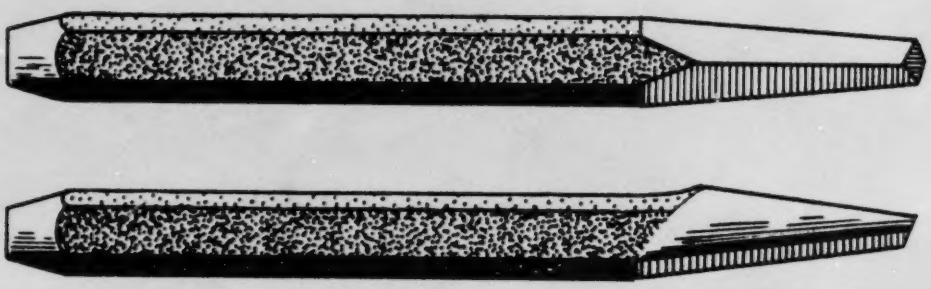


2. THE CAPE CHISEL
The cape chisel has a 40° - 70° point but the cape chisel is narrower than the flat chisel.

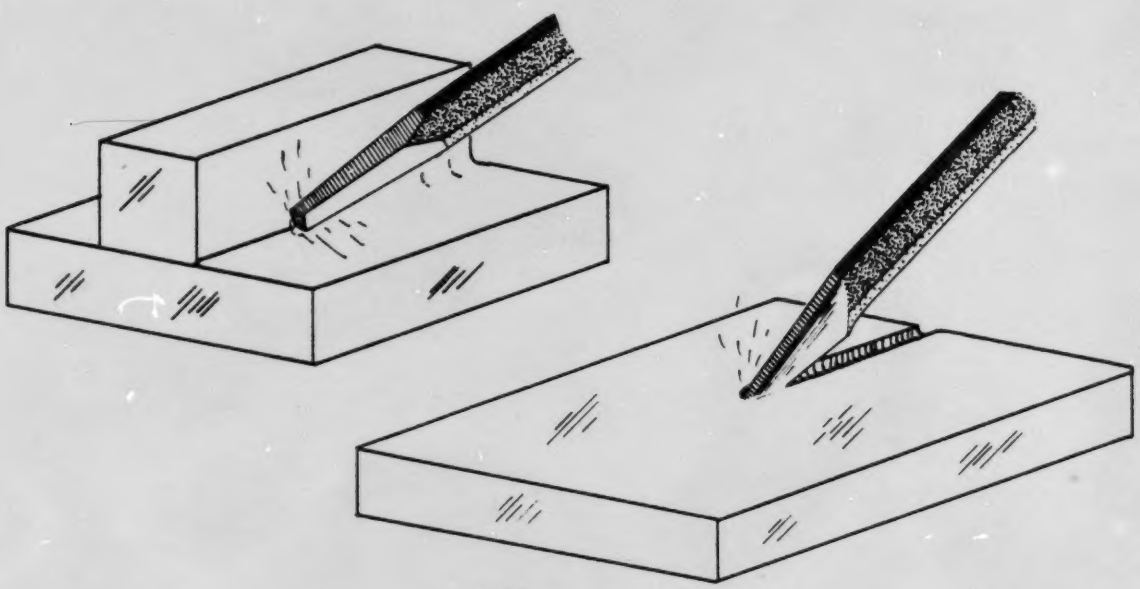


The machinist uses a cape chisel like a flat chisel.
He/she can also cut narrow grooves in parts with a cape chisel.

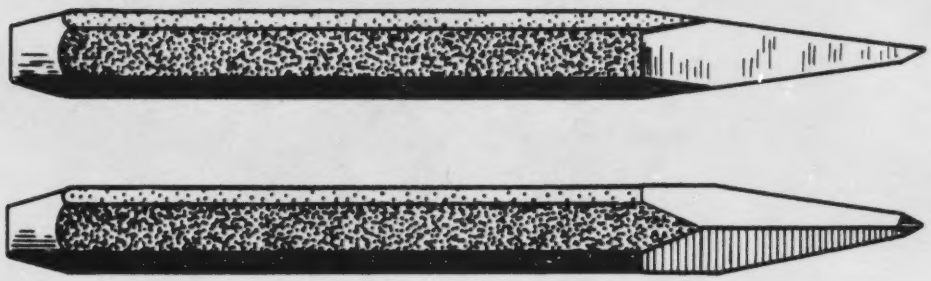
3. THE ROUND NOSE CHISEL



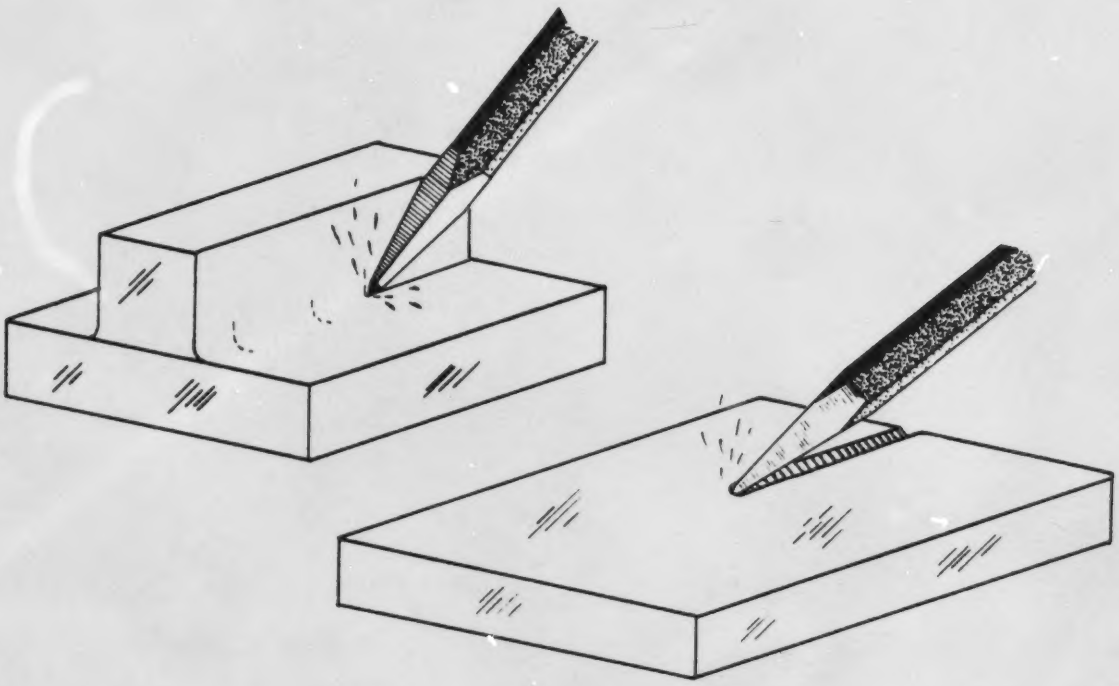
The machinist uses the round nose chisel to cut a radius on an inside corner of a part and to cut grooves with round bottoms in a part.



4. THE DIAMOND POINT CHISEL

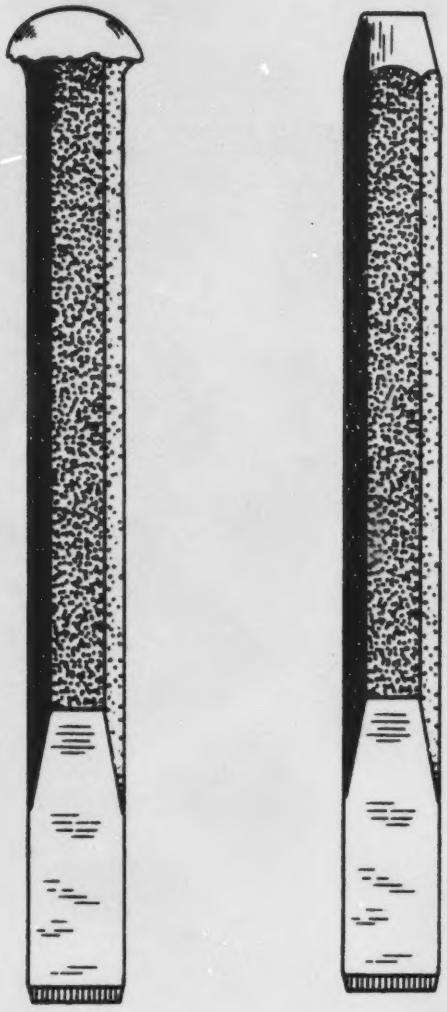


The machinist uses the diamond point chisel to cut a 90° corner on an inside corner of a part and to cut V-grooves in a part.



After the machinist hits a chisel with a ball peen hammer many times, the chisel gets a MUSHROOM HEAD.

INCORRECT CORRECT



A chisel with a mushroom head is very dangerous.
The machinist must grind off the mushroom head on a chisel.

When the point of a chisel gets dull, the machinist must grind the point of the chisel to the correct specifications.
A dull chisel is dangerous.

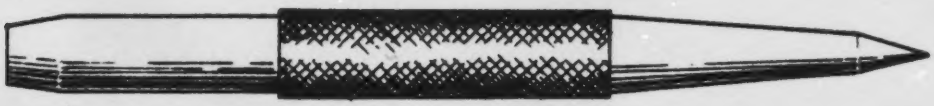
PUNCHES

The machinist uses PUNCHES and a ball peen hammer to mark the center of a radius, the center of a circle, and the center of a hole.

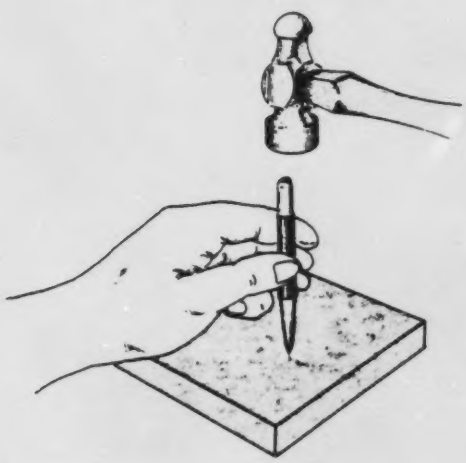
There are 2 main kinds of punches:

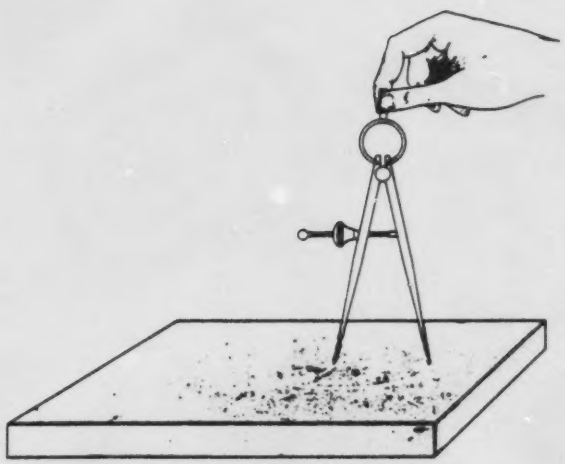
1. THE PRICK PUNCH
2. THE CENTER PUNCH

1. THE PRICK PUNCH



The prick punch has a 30° - 60° point.

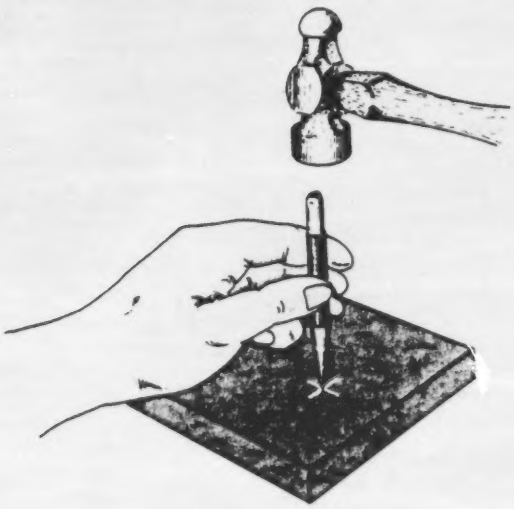


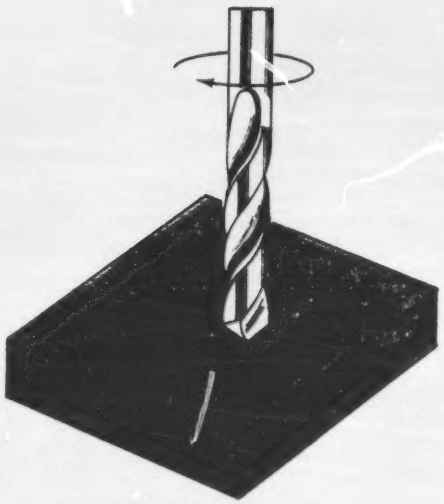


The machinist uses the prick punch to mark the center of a radius and the center of a circle.

2. THE CENTER PUNCH

The center punch has a 90° point.





The machinist uses the center punch to mark the center of a hole.
The point of the center punch makes a dent in the part.
The dent in the part guides the drill bit to the center of the hole.

SAFETY RULES

1. Always wear your safety glasses.

2. Learn how to correctly use a bench tool before you use it.

3. Choose the correct bench tool for the task.

Hammers

4. Do not hit the face of one hammer with the face of another hammer.

5. Make sure the head of the hammer is tight on the handle of the hammer.

6. Hit parts and other bench tools at 90° with the face of the hammer.

7. Carefully put the hammer on the bench.
   Do not put a hammer on a machine tool.
   The hammer can fall and hit your foot.
   The hammer can fall and crack its face.

Chisels and punches

8. Do not use a chisel or a punch with a mushroom head.
   Grind off the mushroom head before you use the chisel or punch.

9. Do not use a dull chisel or a dull punch.

10. Hold a chisel or a punch correctly.
    If you miss the head of the chisel or punch with the hammer, you do not want to hit your fingers.

Machine Shop Fundamentals

7E

UNIT 7: Bench Tools

LESSON 7E: Files

OBJECTIVES:

1. The student will match the name of the shape of a file to a picture of the shape of that file.
2. The student will match the name of the cut of teeth of a file to a picture of the cut of teeth of that file.
3. The student will match the name of the degree of coarseness of a file to a picture of the degree of coarseness of that file.
4. The student will match the name of the filing method to a picture of that filing method.
5. The student will choose the correct safety rules to use files.

PROCEDURES:

1. Read the Objectives.
2. Read the Lesson.
3. Watch the teacher's Demonstration.
4. Do the Study Questions.
5. Do the Worksheets.
6. Do the Review Questions.
7. Do the Self-Test.

REFERENCES:

INTRODUCTION

The machinist uses BENCH TOOLS (hand tools) to do many different tasks. He/she uses bench tools in 3 ways:

1. To set up machine tools
2. To do operations with a machine tool
   (The machinist uses bench tools together with machine tools to do an operation.)
3. To do operations by hand

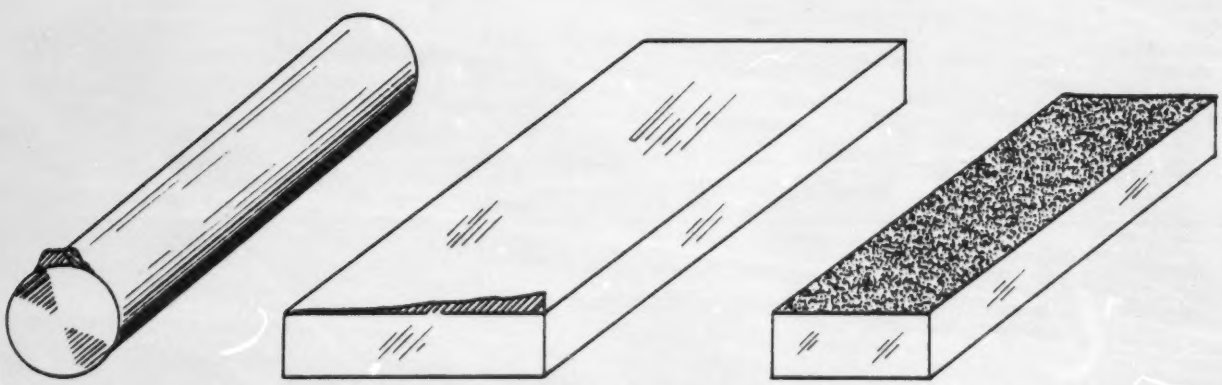
The machinist must choose the correct bench tool for each task.

He/she must learn how to correctly use each bench tool.

He/she must follow the safety rules for each bench tool.

He/she must practice using each bench tool.

Many times, the machinist must remove burrs on parts, remove sharp edges on parts, and make smooth surfaces on parts by hand.

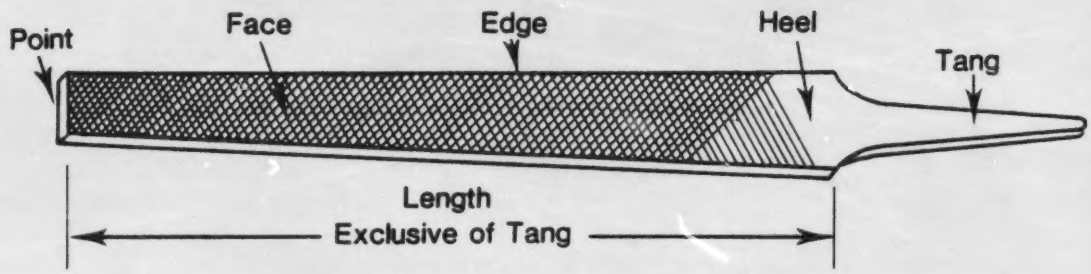


The machinist uses FILES to remove burrs, remove sharp edges on parts, and make smooth surfaces on parts by hand.
The machinist must choose the correct file for each task.

FILES

There are hundreds of different kinds, shapes, and sizes of files.

Parts of a File



Kinds of Files

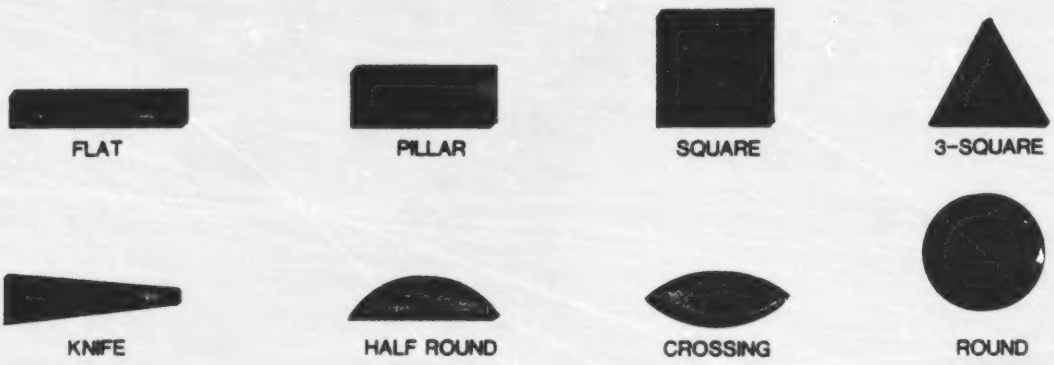
There are 5 main kinds of files:

1. MACHINIST'S FILES
2. MILL FILES
3. SWISS PATTERN FILES or JEWELER'S FILES
4. RASP FILES
5. SPECIAL PURPOSE FILES

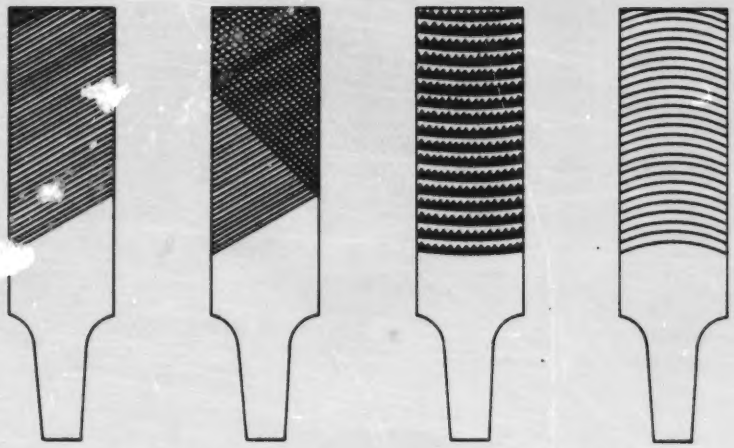
In the machine shop, the machinist usually uses machinist's files and mill files.

For each kind of file, there are different shapes, different cuts of teeth, and different degrees of coarseness.

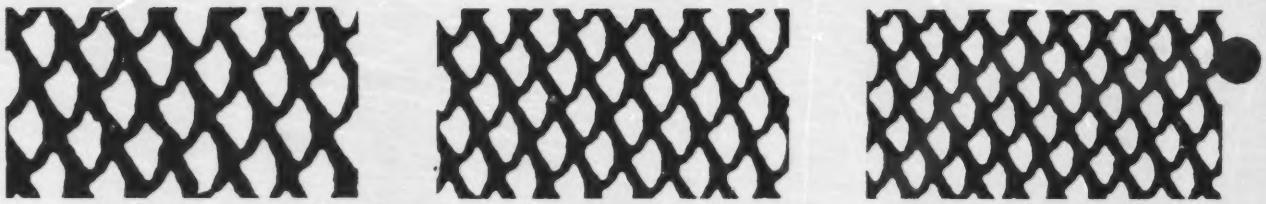
Shapes of Files

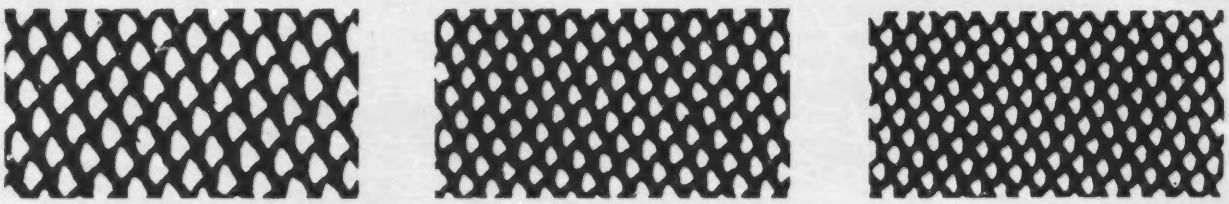


Cuts of Teeth



Degrees of Coarseness





To choose the correct file for a task, the machinist must think about the finished part:

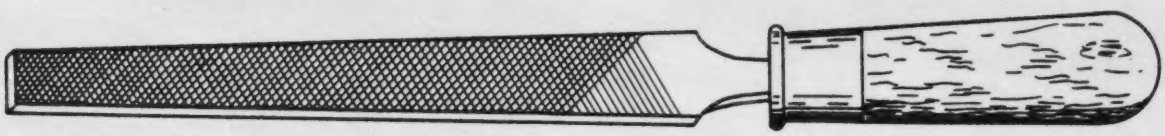
1. The shape of the surface on the finished part (flat, square, round, a radius)
2. The material of the part
3. The amount of material to file off
4. The kind of surface on the finished part (very smooth, smooth, ... rough)

For each task, the machinist must choose the correct kind of file. Then he/she chooses a file with:

- the correct shape
- the correct cut of teeth
- the correct degree of coarseness

USING A FILE

Always use a file with a handle.



NEVER use a file without a handle.

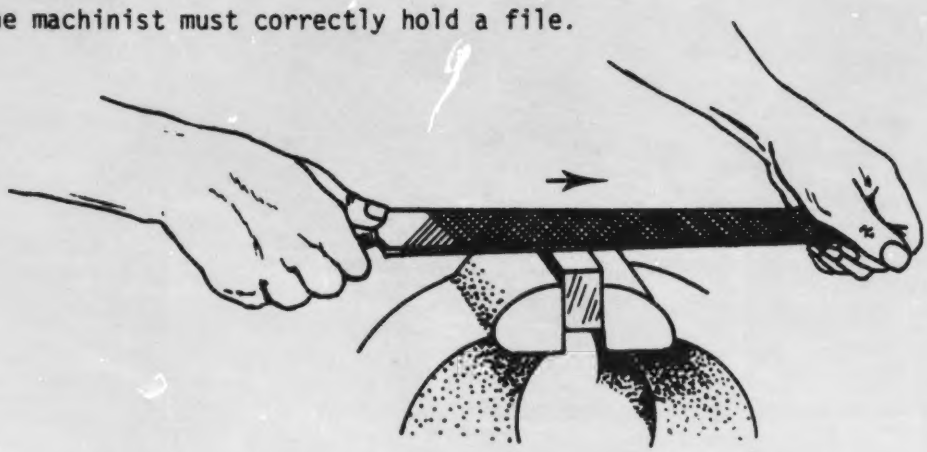
The machinist usually uses a bench vise to hold the part for filing.

Remember, in the machine shop, the machinist usually uses the machinist's files and mill files.

A file cuts in only one direction.
The machinist uses the majority of the teeth of the file to remove metal.

Holding a File

The machinist must correctly hold a file.



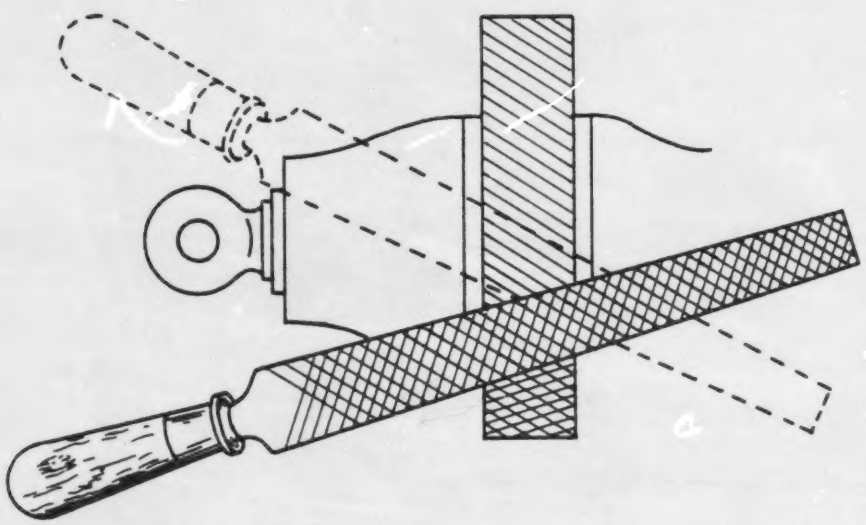
The machinist uses 2 hands to hold a file.

FILING METHODS

The machinist uses 3 main filing methods:

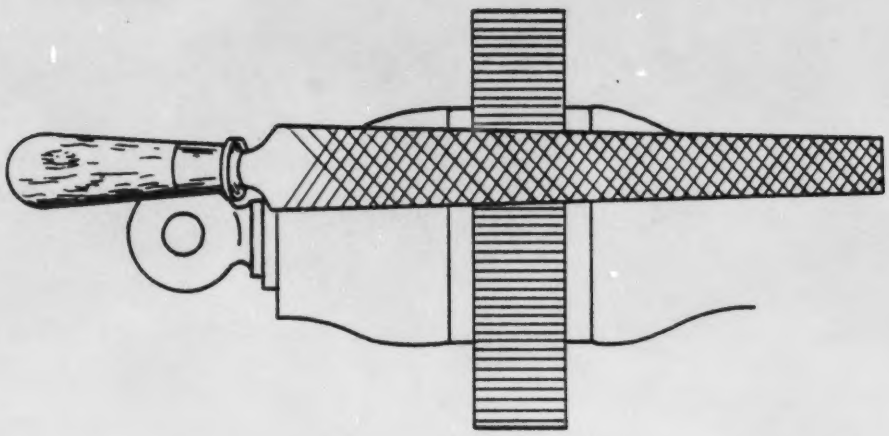
1. The Cross Filing Method
2. The Straight Filing Method
3. The Draw Filing Method

1. The Cross Filing Method



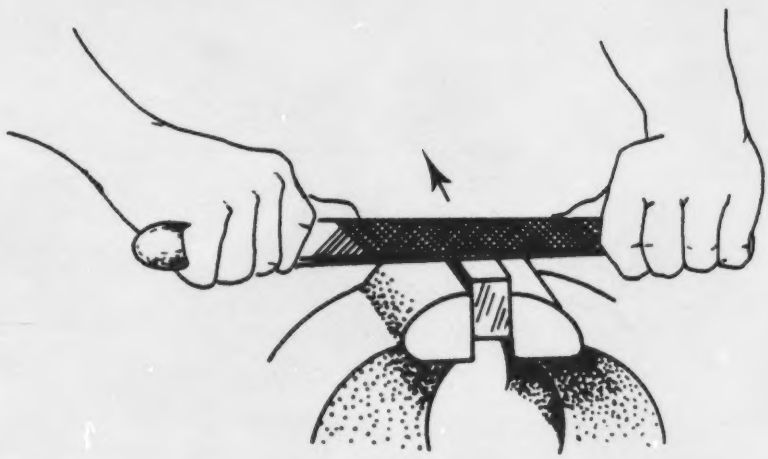
The machinist uses the cross filing method to remove a large amount of material. The surface of the part is rough.

2. The Straight Filing Method



The machinist uses the straight filing method to remove medium to small amounts of material.
The surface of the part can be rough or smooth.

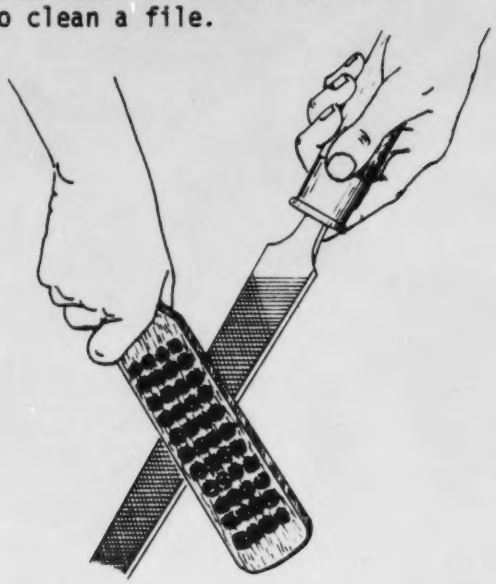
3. The Draw Filing Method



The machinist uses the draw filing method to remove small to very small amounts of material.
The surface of the part is very smooth.

Cleaning a file

Metal chips clog the teeth of a file.
Then, the teeth of the file do not cut.
Also, the metal chips scratch the part.
Frequently, the machinist must clean the file.
The machinist uses a FILE BRUSH to clean the file.
NEVER use your hands to clean a file.



SAFETY RULES

1. Always wear your safety glasses.
2. Learn how to correctly use a bench tool before you use it.
3. Choose the correct file for the task.
4. Do not use a file without a handle.
5. Use a file brush to clean a file.
   Do not use your hands to clean a file.
6. Do not drop a file.
7. Do not carry files in your pocket.

Machine Shop Fundamentals

7F

UNIT 7: Bench Tools

LESSON 7F: Taps and Dies

OBJECTIVES:

1. The student will write the correct definition of tapping.
2. The student will write the correct definition of threading.
3. The student will match the names of the parts of a screw thread to a picture of a screw thread.
4. The student will write the correct major diameter and correct threads per inch from a thread specification.
5. The student will write the correct thread form and correct thread fit from a thread specification.
6. The student will choose the correct methods to measure internal threads and external threads.

PROCEDURES:

1. Read the Objectives.
2. Read the Lesson.
3. Watch the teacher's Demonstration.
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   (He/she uses bench tools together with machine tools to do an operation.)
3. To do operations by hand

The machinist must choose the correct bench tool for each task.

He/she must learn how to correctly use each bench tool.

He/she must follow the safety rules for each bench tool.

He/she must practice using each bench tool.

Many times, the machinist must cut THREADS in a hole in a part.
Many times, he/she must cut THREADS on the outside of a part.
There are two main kinds of threads:

1. INTERNAL THREADS (on the inside of a hole)
2. EXTERNAL THREADS (on the outside of a part)

The machinist can cut threads with a machine tool or by hand.

To cut threads by hand the machinist uses:

1. TAPS
2. DIES

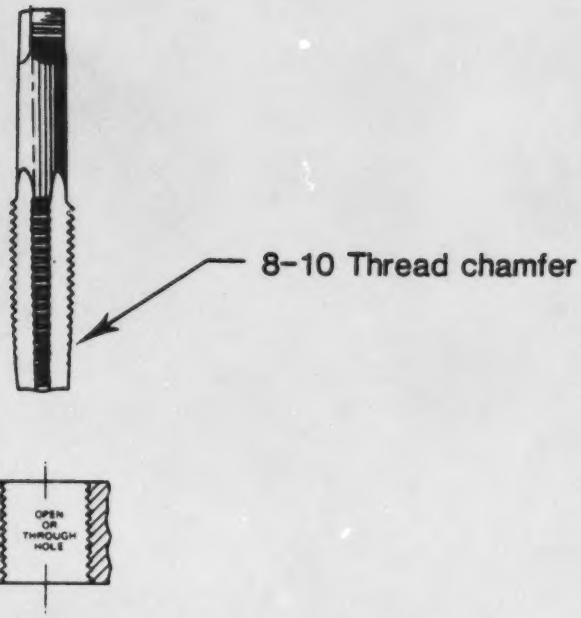
TAPS

Taps are very hard and brittle.
The machinist uses TAPS to cut internal threads.
Cutting internal threads is called TAPPING.

There are 4 main kinds of taps:

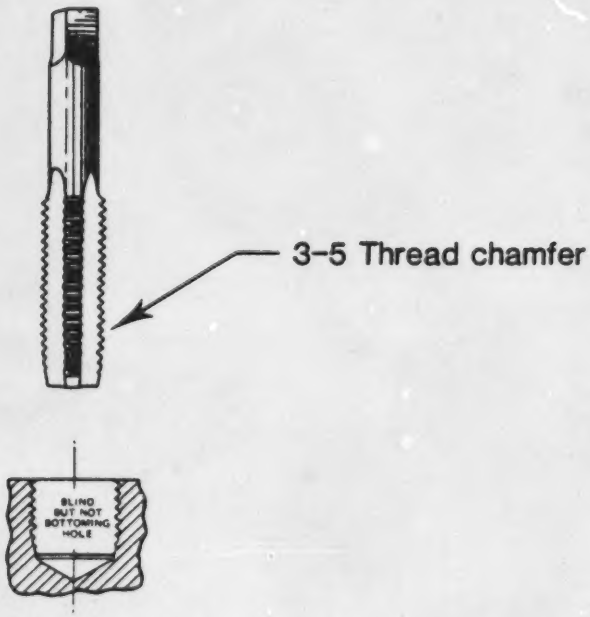
1. TAPER TAPS
2. PLUG TAPS
3. BOTTOMING TAPS
4. PIPE TAPS

TAPER TAPS



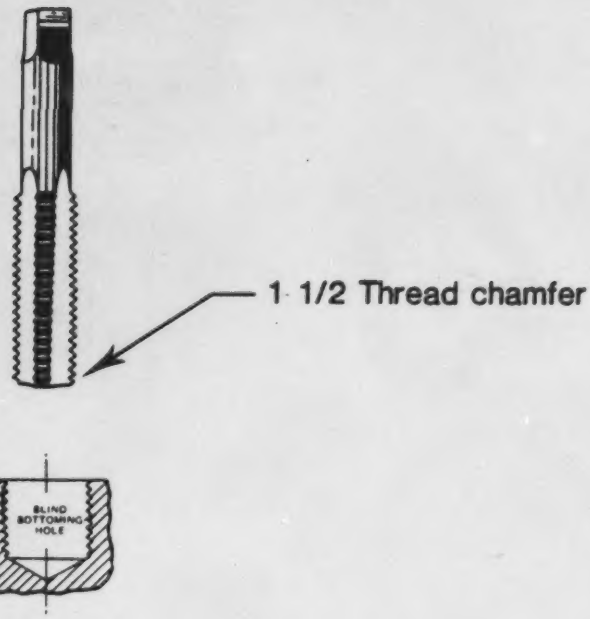
The machinist uses a taper tap to cut threads in holes that go completely through a part.

PLUG TAPS



The machinist uses a plug tap to cut threads in holes that go completely through a part and in blind holes.
(Remember, a blind hole does not go completely through the part.)
To cut threads in a blind hole, first the machinist uses a taper tap to start the threads.
Then he/she uses a plug tap.
The plug tap does not cut threads all the way to the bottom of the blind hole.

BOTTOMING TAPS

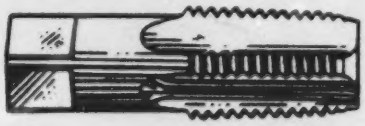


The machinist uses a bottoming tap to cut threads in blind holes.
First, he/she uses a taper tap to start the threads.
Then he/she uses a plug tap to cut more threads.
Finally, he/she uses a bottoming tap.
The bottoming tap cuts threads all the way to the bottom of the blind hole.

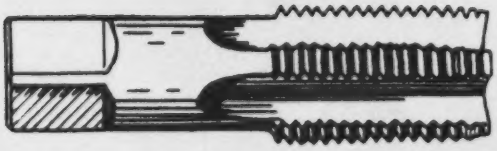
PIPE TAPS

There are 2 types of pipe taps:

a. TAPER PIPE TAPS
b. STRAIGHT PIPE TAPS



TAPER PIPE TAP (NPTF)

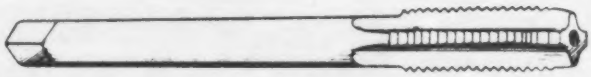


STRAIGHT PIPE TAP (NPSF)

The machinist uses pipe taps to cut pipe threads.

Special Types of Taps

For some tapping tasks, the machinist must use special taps.

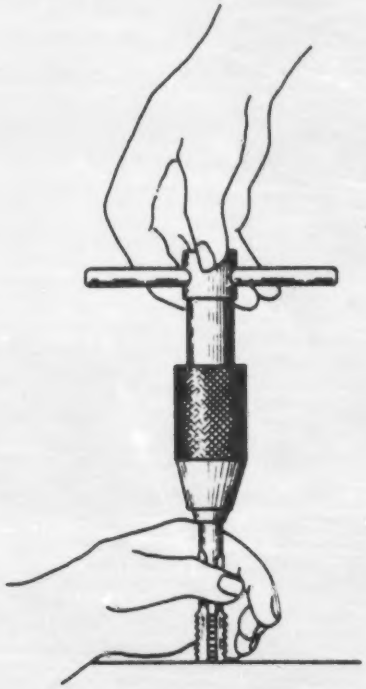


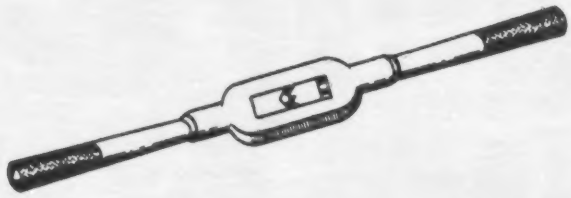
The machinist uses an EXTENSION TAP when other taps are too short.

The machinist uses a PULLEY TAP to tap holes in pulleys.

TAP WRENCHES

The machinist uses a T-HANDLE TAP WRENCH or an ADJUSTABLE TAP WRENCH to hold taps.



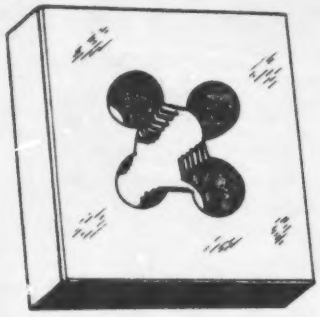


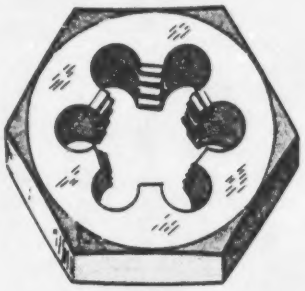
DIES

The machinist use DIES to cut external threads on parts.
Cutting external threads is called THREADING.
There are 2 main kinds of dies:

1. SOLID DIES
2. ADJUSTABLE DIES

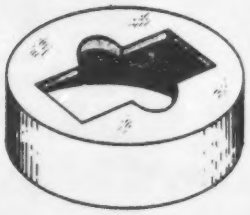
SOLID DIES

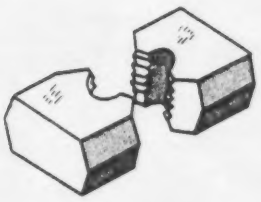




Most of the time the machinist does not use solid dies in the machine shop.

ADJUSTABLE DIES





There are 2 types of adjustable dies:

a. ADJUSTABLE ROUND DIES
b. TWO-PART ADJUSTABLE DIES

The machinist uses taps to cut internal threads in parts.
He/she taps holes in parts.

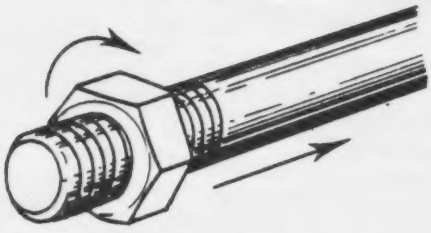
The machinist uses dies to cut external threads on parts.
He/she threads parts.

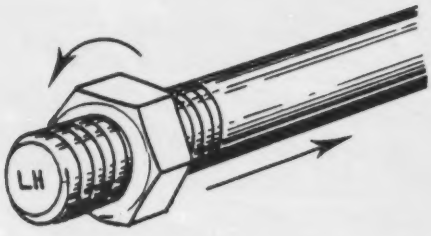
The machinist uses a DIE STOCK (DIE HOLDER) to hold dies.

THREADS

There are two main kinds of internal and external threads:

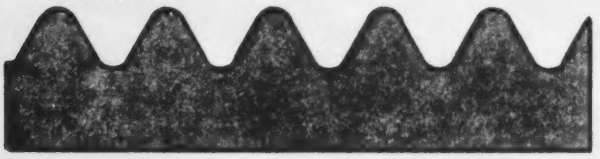
1. Right Hand (RH) Threads
2. Left Hand (LH) Threads





In the machine shop, most machine tools and parts have right hand threads.
Some machine tools and parts have left hand threads.
Usually, the letters LH are on a part, a bolt, or a nut with left hand threads.

Many different companies make bolts, nuts, and parts with threads.
The threads must be the same so different parts from different companies will fit together.
Many companies use the UNIFIED NATIONAL THREAD Form.



Unified national threads

American national threads

60° Vee threads

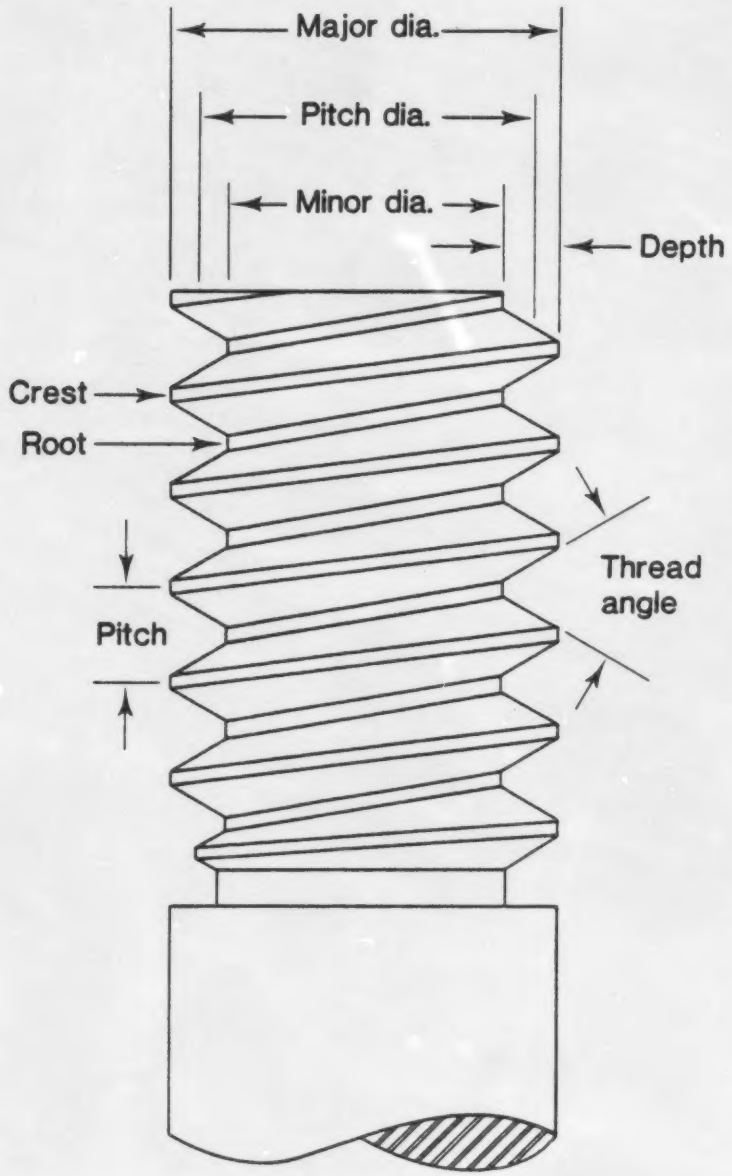
Acme threads

These are the abbreviations for Unified National threads:

Unified National Coarse (UNC)
Unified National Fine (UNF)
Unified National Extra Fine (UNEF)
Unified National 8-Pitch (8 UN)
Unified National 12-Pitch (12 UN)
Unified National 16-Pitch (16 UN)

The machinist must know the PARTS OF SCREW THREADS.

Parts of Screw Threads



MAJOR DIAMETER - The major diameter is the outside diameter of external threads.

MINOR DIAMETER - The minor diameter is the smallest diameter of the thread.

PITCH DIAMETER - The pitch diameter is halfway between the major diameter and minor diameter.
The pitch lines go through the threads and the grooves.
The distance through the threads and through the grooves is the same.

PITCH - Pitch is the distance between an exact place on one thread and the same exact place on the next thread.

$$\text{Pitch} = \frac{1}{\text{Number of threads per inch}} \quad \text{or} \quad \text{Number of threads per inch} = \frac{1}{\text{Pitch}}$$

ROOT - The root is the bottom or base of the thread.
The machinist measures the minor diameter at the roots of the threads.

CREST - The crest is the top of the thread.
The machinist measures the major diameter at the crest of the threads.

THREAD ANGLE - The thread angle is the angle between two threads.

DEPTH OF THREADS - The depth of threads is the vertical distance between the crest and the root of the thread.

LEAD - The lead is the distance a nut will move in one revolution on threads.

Screw Thread Fits

There are three kinds of thread fit:

Class 1 - Loose Fit
Class 2 - Medium Fit
Class 3 - Tight Fit

The three kinds of thread fit use the letters A and B:

A is for external threads.
B is for internal threads.

For example:

Class 1 A means loose fit for external threads
Class 2 B means medium fit for internal threads.
Class 3 B means tight fit for internal threads.
Class 3 A means tight fit for external threads.

THREAD SPECIFICATIONS

The machinist reads a blueprint to find the thread specifications of a part.

EXAMPLE A

1/2 - 13 UNC - 2A

In EXAMPLE A, the major diameter of the thread is $\frac{1}{2}$"
There are 13 threads per inch.
The screw thread form is Unified National Coarse.
The thread fit is a medium fit for external threads.

EXAMPLE B

1/4 - 20 UNF - 3B

In EXAMPLE B, the major diameter of the thread is $\frac{1}{4}$"
There are 20 threads per inch.
The screw thread form is Unified National Fine.
The thread fit is a tight fit for internal threads.

EXAMPLE C

3/4 - 20 UNEF - 3A

In EXAMPLE C, the major diameter is $\frac{3}{4}$"
There are 20 threads per inch.
The screw thread form is Unified National Extra Fine.
The thread fit is a tight fit for external threads.

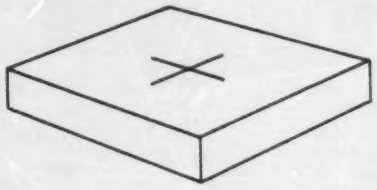
TAPPING

The machinist uses taps to cut internal threads in parts.

To tap a hole, first the machinist drills the hole.
Then he/she taps the hole.
The machinist uses a drill bit to drill the hole.
Many times, this drill bit is called a TAP DRILL.
The machinist usually follows these steps to tap a hole.

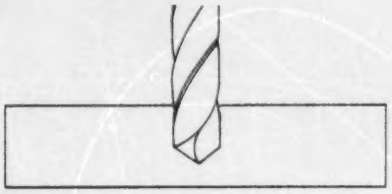
STEP 1. The machinist reads the blueprint to find the dimensions of the center of the hole and the specifications of the threads.

STEP 2. He/she lays out the center of the hole.



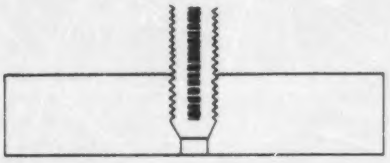
STEP 3. He/she reads the TAP DRILL SIZES CHART to find the correct tap drill size.

STEP 4. He/she drills the correct size hole.



STEP 5. He/she chooses the correct size tap.

STEP 6. He/she taps the hole.
He/she usually uses a bench vise to hold the part.



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EXAMPLE D

Thread specifications: $\frac{1}{2}$ - 20 UNF - 2A

The machinist finds $\frac{1}{2}$ - 20 on the TAP DRILL SIZES CHART.

NATIONAL COARSE AND FINE THREADS	
Thread	Drill
1/2 - 13	27/64
1/2 - 20	29/64
9/16 - 12	31/64
9/16 - 18	33/64
5/8 - 11	17/32
5/8 - 18	37/64
3/4 - 10	21/32
3/4 - 16	11/16
7/8 - 9	49/64
7/8 - 14	13/16
1 - 8	7/8
1 - 14	15/16
1-1/8 - 7	63/64
1-1/8 - 12	1-3/64
1-1/4 - 7	1-7/64
1-1/4 - 12	1-11/64
1-1/2 - 6	1-11/32
1-1/2 - 12	1-27/64
1-3/4 - 5	1-35/64
1-3/4 - 12	1-43/64
2 - 4 1/2	1-25/32
2 - 12	1-59/64
2-1/4 - 4-1/2	2-1/32
2-1/2 - 4	2-1/4
2-3/4 - 4	2-1/2
3 - 4	2-3/4

Then, he/she reads $\frac{29}{64}$ tap drill size.

For the $\frac{1}{2}$ - 20 threads in EXAMPLE D, the correct tap drill is $\frac{29}{64}$"

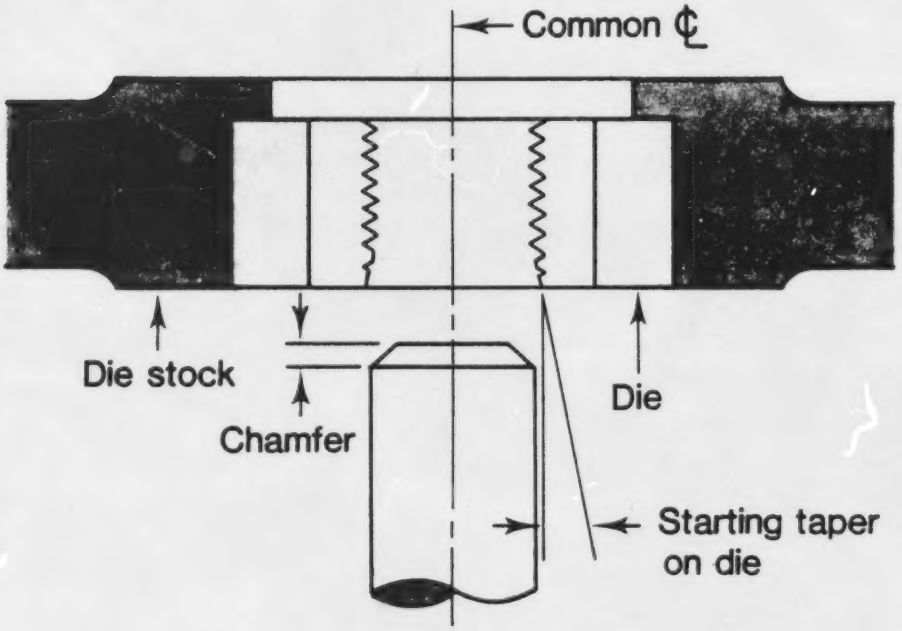
For $\frac{3}{4}$ - 16 threads, the correct tap drill is $\frac{11}{16}$"

For 2 - 12 threads, the correct tap drill is 1 $\frac{59}{64}$"

THREADING PARTS WITH DIES

The machinist uses dies to cut external threads on parts.

Most dies have a STARTING TAPER on one side of the die.



The starting taper helps the die begin cutting the threads.

The machinist uses the side of the die with a starting taper to begin threading the part.

The machinist usually follows these steps to thread a part.

STEP 1. The machinist reads the blueprint to find the specifications of the threads.

STEP 2. He/she measures the diameter of the part to make sure it is the correct diameter.

STEP 3. He/she files or grinds a small chamfer on the end of the part.
A CHAMFER is a small angle cut (bevel cut) on the edge of a part.
The chamfer helps the die to start the threads.

STEP 4. He/she chooses the correct die.

STEP 5. He/she threads the part.
He/she usually uses a bench vise to hold the part.

CUTTING OIL

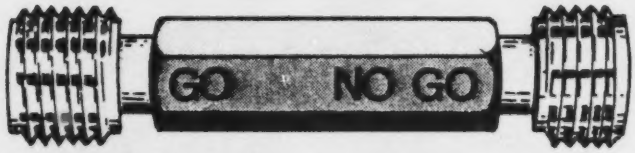
Most of the time, the machinist uses CUTTING OIL with taps and dies.

The cutting oil helps taps and dies cut good, clean threads.
The cutting oil also helps remove the metal chips.

But, do not use cutting oil on cast iron parts.
The machinist reads a chart to find the correct cutting oil for each task.

MEASURING THREADS

Most of the time, the machinist uses a GO - NO GO GAGE to measure internal threads.



If the "GO" side of the go - no go gage fits the threads and the "NO GO" side does not fit the threads, then the threads are accurate.

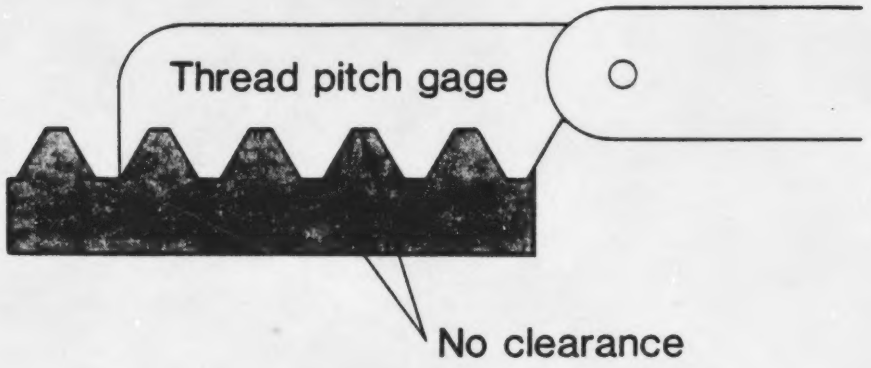
If the "GO" side of the go - no go gage fits the threads and the "NO GO" side also fits the threads, then the threads are not accurate.

These are four main ways to measure external threads:

1. Use a thread pitch gage
2. Use a ring gage
3. Use a thread micrometer
4. Use the 3-wire method

1. THREAD PITCH GAGE

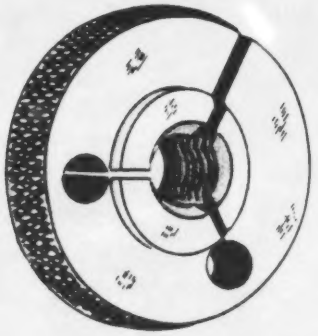
Hold the thread pitch gage against the threads and check for clearance.
Clearance is space between the thread pitch gage and the threads.



If there is no clearance, then the threads are accurate.
If there is clearance, then the threads are not accurate.

2. RING GAGE

A ring gage is like a nut.
The machinist chooses the correct ring gage to measure the thread.
For example, for a $\frac{1}{2}$" - 14 UNC 2A thread specification, the machinist will use a ring gage with a $\frac{1}{2}$" major diameter, 14 threads per inch in Unfied National Coarse, and a medium fit.
Turn the ring gage on the threads.
If the threads are too big, the ring gage will not turn on the threads.
If the threads are too small, the ring gage will turn on the threads but it will fit too loose.
If the threads are correct, the ring gage will turn on the threads and have the correct fit.



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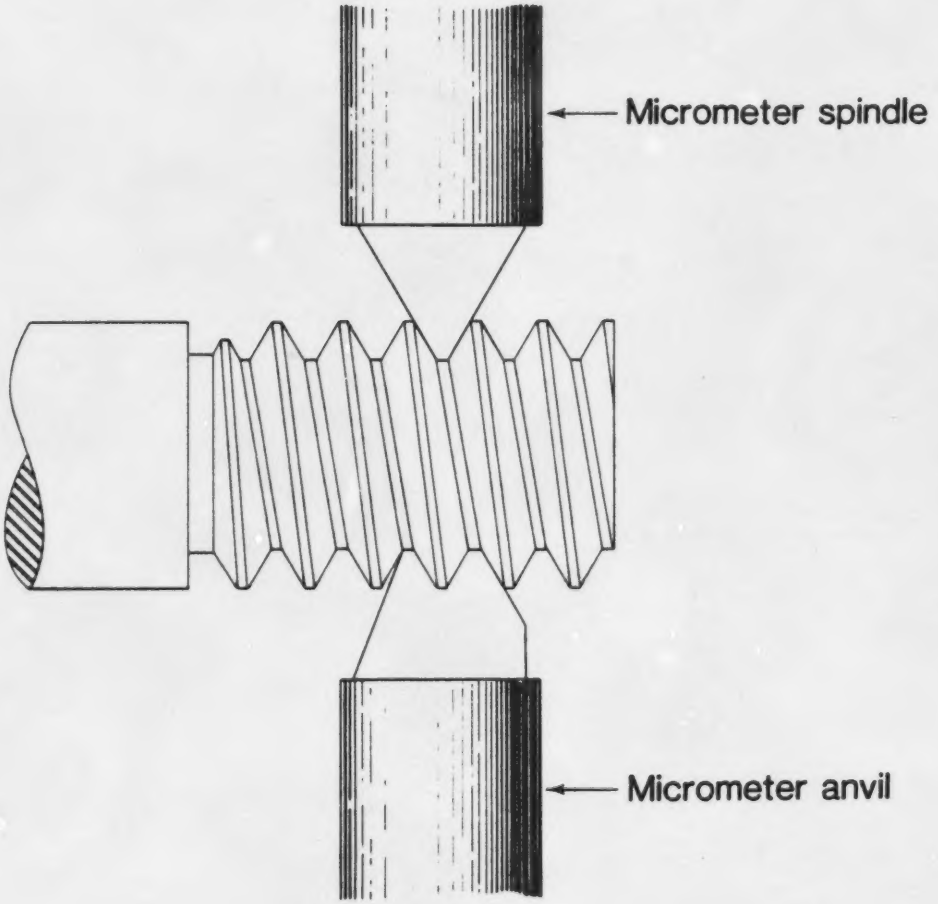
3. THREAD MICROMETER

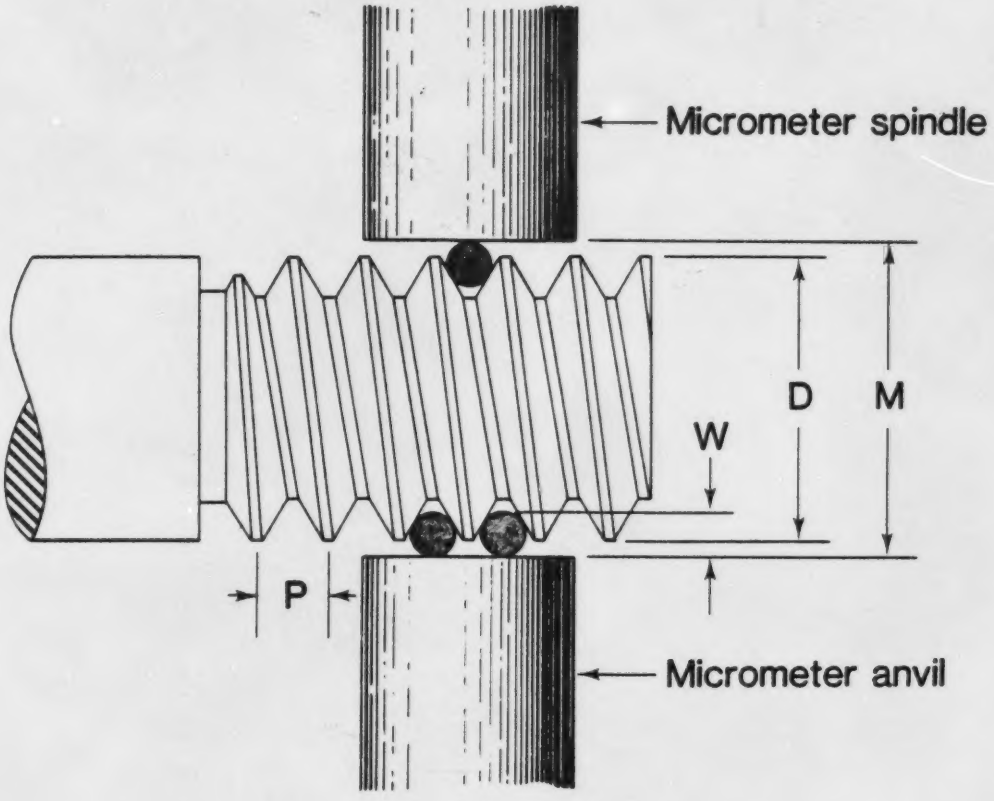
The thread micrometer measures the pitch diameter of threads.
The machinist reads the pitch diameter of a thread from a blueprint or chart.
Then, he/she gets the correct thread micrometer.
The number of threads per inch the thread micrometer can measure is on the frame of the micrometer.
The machinist measures the thread pitch diameter.
He/she reads a thread micrometer like other outside micrometers.



If the measurement on the thread micrometer is within tolerance, then the threads are accurate.
If the measurement on the thread micrometer is not within tolerance, then the threads are not accurate.

4. 3-WIRE METHOD

The machinist uses 3 wires of the same diameter and an outside micrometer for the 3-wire method to measure threads.



M = Micrometer measurement over wires.
D = Major Diameter of threads
W = Diameter of the wires
N = Number of threads per inch
P = Pitch

The machinist measures the threads with the 3-wire method.
If the measurement on the micrometer is within tolerance, then the threads are accurate.
If the measurement on the micrometer is not within tolerance, then the threads are inaccurate.
The machinist does not often use the 3-wire method.

SAFETY RULES

1. Always wear your safety glasses.
2. Learn how to correctly use a bench tool before you use it.
3. Choose the correct tap for each task.
4. Choose the correct die for each task.
5. Use a bench vise or clamp to hold the part.
6. Use a brush or shop towel to wipe off metal chips.
   Do not use your hands to wipe off metal chips.
7. Wash your hands after you use cutting oil.